A MANUAL

OF

FOREST ENGINEERING FOR INDIA.

Agents for the sale of Books published by the Superintenden of Government Printing, India, Calcutta.

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E. A. Arnold, 37, Bedford Street, Strand, London, W. C.
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IN INDIA.

Thacker, Spink & Co., Calcutta and Simla.
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A MANUAL

OF

FOREST ENGINEERING FOR INDIA

BY

CHARLES GILBERT ROGERS,

FELLOW OF COOPER'S HILL, DEPUTY CONSERVATOR OF FORESTS, IMPERIAL FOREST SERVICE OF INDIA.

VOLUME III.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1902.

Price Five Rupees.
English Price Seven Shillings Six Pence.

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

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SECTION I.—DIFFERENT METHODS OF TRANSPORT.

§ 1. Timber and firewood may be transported—

I. BY LAND.

II. BY WATER.

I. BY LAND.—If transported across land, timber and firewood may be conveyed—

A. *on ordinary roads or paths*—

(*a*) by men,

(*b*) by animals,

(*c*) in carts.

B. *on roads specially constructed for the purpose, such as*—

(*a*) rolling roads,

(*b*) sledge roads,

(*c*) tramways.

C. *in specially prepared troughs and slides*—

(*a*) earth slides,

(*b*) dry wooden slides,

(*c*) wet wooden slides.

In the first two of these three methods the logs or scantlings move down the slide in virtue of their own weight; in the third the motive power is supplied, to a greater or less extent, by water.

D. *by inclined wire-rope ways.*

E. *without roads by means of*—

(*a*) elephants, buffaloes and oxen; and in Europe horses.

(*b*) mechanical contrivances.

II. BY WATER.—When timber or firewood is transported by water, it may be—

A. Allowed to drift.

B. Rafted.

C. Carried in boats or ships.

Manual labour in India is very cheap, and in consequence mechanical means of transport having in view the saving of manual labour, such as rolling roads, sledge roads, tramways, inclined wire-rope ways and mechanical contrivances, have not been generally developed to the same extent as in Europe and America, where manual labour is expensive. Consequently the subject of the judicious extension of mechanical means of transport in India still remains to be further studied.

In Burma manual labour is expensive and difficult to obtain, but good natural floating streams are usually available. Up to the present time only those forests, which are traversed by streams that can be utilized as floating channels during the rains, have been worked to any great extent. The logs are dragged, during the dry season, by buffaloes or elephants, or are conveyed on timber-carts drawn by buffaloes or elephants, from the places where the trees are felled to the banks of the floating streams.

§ 2. Where good floating streams exist, and there are no roads, transport by water is always much cheaper than transport by land. In Germany transport by water was formerly considered in all cases to be the best mode of transport where circumstances permitted of its being adopted; and very extensive works were undertaken to train small streams in order to make them serviceable for the floating of timber or firewood. Large masonry dams were built across the beds of small hill streams, in order to obtain a sufficient volume of water to allow of the portion of the stream below the dam being used for floating purposes; while costly mechanical contrivances were constructed across the larger streams in order to catch the floating logs and firewood and divert them into specially prepared depôts.

In the Schwarzwald at Herrenwies up to 1860 floating was the rule, and the remains of the very elaborate arrangements

for storing water and training the small rivulets used, still exist. A new cart-road was constructed in order to open up the country (not by the Forest Department, or with a view of opening up the forests) and since then the timber from the Herrenwies forests has gone over this road to supply sawmills to the west of the Schwarzwald.

The use of small streams, which required constant training, in the Bavarian Alps and Salzkammergut district, is being superseded by transport along roads, because it is cheaper to construct roads than to rebuild the floating works where the latter have fallen into disrepair; and also because the roads and paths made can be used for general traffic as well as, and in addition to, the transport of wood. Large rivers like the Rhine will always be used for the transport of timber; nearly all the spruce and fir logs used in Holland are, and always will be, rafted down it on account of the small cost of transport.

If floated timber is properly dried when it is taken out of the water, or cut up at once and seasoned, the wood will not be attacked by fungi and deteriorate in consequence. But if floated timber is taken out of the water and stacked in huge heaps, without proper ventilation, fungoid diseases are likely to develop on a large scale in the wood. Where stacking of the wood is unavoidable many wood-merchants prefer transport by land to transport by water.

§ 3. In India land transport can never entirely supersede water transport, because the forests are, in the majority of cases, far removed from the large markets; no means of natural land transport exist; and, unless water transport were adopted, it would be impossible to work the forests at a profit. So far as we know at present, the durability of the various kinds of Indian timbers which are largely transported by water has not been injuriously affected by their prolonged exposure and immersion in water. On the contrary the durability is increased especially in the case of bamboos, logs and poles containing little or no heart wood. The immersion and floating dissolves out materials which would otherwise ferment or serve as food for insects.

Teak logs are floated down streams in Burma, from the place where they are felled (if we except the distances, which do not as a rule exceed 2 or 3 miles, which they are dragged or carted to the nearest floating stream), to the market at Rangoon or Moulmein, as the case may be.

The logs from Upper Burma are floated on an average a distance of from 400 to 500 miles, and in Lower Burma from 50 to 200 miles before reaching Rangoon.

The timber is placed in the dry beds of the small floating channels during the dry season (December to April), and generally reaches Rangoon during the following autumn and cold season (November to February): but in seasons when the rainfall is deficient, more particularly in Upper Burma, the timber becomes *neaped* or stranded at the end of the first floating season, or in some cases is not floated at all, and can only be extracted when the next monsoon breaks. Such neaped or stranded timber has often to be dug out of the sand in the bed of the streams and placed in a free position so that it may float down easily during the following rains. Logs placed in some of the small floating streams in Upper Burma occasionally take three, four or even a longer number of years to reach the main rafting stream.

§ 4. FINANCIAL ASPECT OF MECHANICAL MEANS OF TRANSPORT.—Before any works, such as slides, sledge-roads, tramways, or inclined rope-ways, are commenced, with a view to cheapen or facilitate the transport of timber, firewood, or other forest produce, it must be clearly proved that their introduction will cause a direct saving, or that if constructed they will allow of forests which were formerly considered to be inaccessible being worked at a profit.

In order to do this it is necessary to ascertain—

(1) the capital expenditure on the construction of the proposed labour-saving appliance;

(2) the number of years that the labour-saving appliance will remain in working order;

(3) the annual cost of working the proposed labour-saving appliance, repairing it and keeping it in working order;

(4) compound interest on the capital expended;

(5) the annual and total amount of produce which will be removed through its agency;

(6) the cost of transport by the existing means available;

(7) the beneficial results on the produce transported.

The following indirect advantages should also be taken into consideration:—

(1) The saving of time consequent on the introduction of the new means of transport.

(2) The saving of manual labour.

The introduction of a mechanical means of transport is justifiable when it can be shown that the net saving in the cost of carriage of the produce is sufficiently large to more than repay the capital outlay together with compound interest on this sum within a *definite* term of years, and provided of course that the market is a constant and reliable one.

Before the introduction of any labour-saving appliance can be recommended it must be clearly demonstrated that either—

(1) a direct saving in the cost of transport will result from its introduction, or

(2) that the introduction of the labour-saving appliance advocated will prevent a rise in the cost of transport, and thus indirectly produce a saving.

The introduction of a labour-saving appliance must be accompanied by a reduction in the *actual* cost of transport of the forest produce concerned; and this direct saving must be sufficient to pay for the initial cost of the labour-saving appliance within a reasonable term of years, and also the interest on the capital charges.

As a general rule it may be stated that unless a considerable amount of forest produce is available for extraction, or unless the produce will pass over the same line for several years, the

introduction of a labour-saving appliance which involves a large initial outlay is not warranted.

The total amount of produce which is available for transport, the time during which the appliance can be used, and the direct saving in transport are the three principal points which must be considered before the advisability or otherwise of the introduction of a labour-saving appliance can be demonstrated.

Another point to be considered is the amount of direct loss and damage done to the produce during transit. The introduction of a labour-saving appliance is often accompanied by a considerably smaller direct loss of the produce transported; and also allows of produce reaching its destination in a much better state of preservation. Both these factors may increase the value of the produce transported and its sale price.

In districts where manual labour is scarce and a sufficient number of men, cattle, or carts cannot be obtained to transport the produce, the introduction of a labour-saving appliance may be justifiable, even if the cost of extraction is as great as, or in exceptional cases even slightly greater than, the cost of extraction by the *existing* means at the rates in force for the time being. If local labour and transport be solely relied upon in agricultural districts where the villagers keep only sufficient cattle to work the land under cultivation, and no other draught cattle exist, then carts and cattle will not be available for transport of forest produce at those periods of the year when the land has to be prepared for the crops, and at the time that the crops are reaped, and a rise in the rates paid for the carriage of forest produce would inevitably result.

Another point must be remembered, and that is, that the labour-saving appliance must be worked to its utmost capability if the best results are to be obtained from it, and this is a point which is often lost sight of. Take for example the case of a tramway and wagons for the transport of fuel. Say that we have a rolling-stock of 30 fuel trucks. In order that the greatest amount of profit may be obtained from the tramway, every one of these trucks should be used every working day in the year to its utmost capacity. If the trucks are only used for

six months in the year, then it is evident that the net saving in transport is only one-half of what it might have been had the trucks been in full use for the whole of the year. Consequently, before introducing any labour-saving appliance, it is necessary to make a forecast of the actual total saving in transport that is anticipated, and to consider whether this is sufficient to warrant the introduction of the labour-saving appliance in question.

In a thinly populated or unhealthy district, or in one which is barren and where provisions are expensive or have to be imported departmentally, the use of some mechanical means of transport will probably be a financial success, provided the quantity of wood or other produce to be removed is sufficiently large and the market is a constant and reliable one.

In cases where all the produce of a forest has to pass along one line in order to reach the market, the introduction of some labour-saving means of transport along this line may often prove to be advantageous. The more scattered the working the smaller will be the advantages to be derived from mechanical means of transport.

Both the *indirect* advantages noted on page 5 may be of great importance when the quantity of produce to be removed is large and the working-season short.

As a rule, however, in India at the present time transport by land is still usually effected by the aid of men and pack and dragging animals in the hills, and by pack and dragging animals and carts in the plains. Elephants, buffaloes and bullocks are used to extract timber in low hills and flat country where no roads have been made. The fluctuating nature of the demand, which in many cases is confined to one species of tree only, growing in a mixed forest and often forming only a small proportion of the growing stock, as well as the large and scattered nature and great extent of the forests from which the produce is obtained, often reduce very much the advantages to be gained by such labour-saving appliances as have been adopted with success in European countries, where a market can be obtained for nearly

every forest product, and where a concentrated system of working can, as a rule, be adopted.

In India, the demands on the forests are, in the majority of cases, almost entirely local; and in cases where the demand is not purely local, the distances over which the timber has to be carried are usually so great that mechanical contrivances are only used to transport the logs, or converted timber, from the forest to the banks of the nearest floating or rafting stream.

SECTION II.—TRANSPORT ALONG ORDINARY ROADS OR PATHS.

§ In the mountainous districts of India very few cart roads have as yet been made for the extraction of forest produce, as the export of forest produce alone is not sufficiently large to warrant their construction, and in the large majority of cases there is nothing else to export.

Cart-roads have been made from the plains to some of the chief of the hill stations, and have, in some instances, been continued into the neighbouring forests with a view to supplying the station with timber, firewood, and other forest products; but in many mountainous districts the whole of the land transport *is still effected by men and laden animals.*

§ 6. TRANSPORT BY MEN.—Bridle-paths, along which laden men and animals can pass, may be constructed at a comparatively low cost in the mountainous parts of the country; and such forest produce as is exported by land is usually carried along them either by men or. beasts of burden. Sleepers, firewood, and grass are carried by men, or pack animals when available; while scantlings and planks, in the absence of cart-roads, are carried almost exclusively by the former agency. In India (but not in Burma), as a rule, the trees are converted in the forest into sleepers, beams, scantlings and planks, and these in the hills are carried or dragged by men to the nearest path and are then transported along these paths to their destination.

The bridle-paths wind round the slopes of the hills, following the configuration of the ground as closely as possible; and in consequence have such sharp curves, that if long planks or beams were carried by mules, ponies, or bullocks, the latter would be in danger of losing their balance and falling over the edge of the path and being killed, when going round a sharp corner, owing to one end of the plank or beam striking against the inner side of the path. Where the paths pass through very precipitous ground, wooden railings are often placed along the outer edge for the protection of the traffic, and in these places a pony or mule laden with long planks could not pass round the curve.

In many parts of the hill forests on the Himalayan mountain range the transport of timber only takes place during five or six months of the year, either on account of the rainy season or because the roads are blocked by snow; and in these cases the use of animals as a means of transport is, so far as the Forest Department itself is concerned, out of the question, unless some other work can be found for the animals during the remaining portion of the year.

Forest officers should recollect, before attempting the introduction of pony transport, that great difficulties may ensue through epidemics.

The nature of the demand determines also to a great extent the agency employed in the transport of timber or other forest produce. In India the produce is, as a rule, sold in the forest and is removed by the purchaser. The chief purchasers are small timber merchants and the surrounding villagers; in the latter case the villagers themselves go to the forest and convert and remove such timber, firewood, or other produce as they may have purchased. The inhabitants of the villages near the forests, as a rule, remove such produce as they require for their own consumption, and they rarely purchase forest produce with a view to selling it again at a profit, while the small timber merchants usually employ that kind of transport which is available locally.

In Burma, teak logs are extracted by water, and in the Punjab, some logs of deodar and other conifers are still, to some extent, floated down the Ravi and other rivers. Formerly all the conifers that were extracted from the Punjab Himalaya were removed from the forest in the log, but now the export of timber in the log has been almost entirely given up as the nature of the demand has changed, owing to the introduction of iron beams in the construction of houses and bridges, and the trees are now generally converted in the forests and exported as sleepers, beams, scantlings, etc.

§ 7. TRANSPORT BY ANIMALS.—Camels, mules, donkeys, ponies, buffaloes and bullocks are used in transporting timber and firewood in different parts of India. Elephants are used chiefly for dragging logs out of the forests either to the side of a cart-road or to the bank of a stream. Camels, ponies and mules carry the whole weight on their backs, whereas buffaloes and bullocks usually only drag their loads (logs, scantlings, poles or bamboos) through the forest or along rough export paths to the nearest cart-track. The process of dragging wood along *metalled roads* or along the main lines of communication should never be allowed, whenever these roads are passable for carts, on account of the damage done by dragging to the surface of the road.

The dragging of scantlings, small poles, bamboos, etc., should always be discouraged wherever any other means of transport exists.

When animals are used to carry firewood or scantlings some precautions must be taken to prevent their backs from being rubbed. Usually a pad, in the shape of a narrow horse-shoe stuffed with fibre or straw, is placed on the animal's back so as to protect its backbone, and is fastened in position by ropes passing around the animal's body, the load being slung over this pad. This kind of pad forms a very imperfect protection, as is demonstrated by the number of pack animals which have or have had sore backs. Sore backs, though primarily due to a badly fitting pad, are almost invariably very much aggravated by the owners of the pack animals working them

when their backs are slightly rubbed and continuing to make them carry loads until their backs are in such a state that they can no longer bear any pressure on them. A fertile source of sore backs is the working of the animals when their backs are wet.

§ 8. PONIES AND MULES.—Figures 1 and 2 (below) show the saddle used for fuel ponies and mules in the Jaunsar Forest Division, instead of the pad in common use by the natives of India for the transport of fuel, grain and food-stuffs generally.

The curved portions of the saddle are made of *karshu* or *moru oak*.

The flat portions (*c*, *c*) which rest on the saddle cloth are made of *rai*, while the small rods (*b*, *b*) are made of *râuns*. The curved portions (*a*, *a*) are nailed on to the flat pieces of wood (*c*, *c*).

FIG. 1.

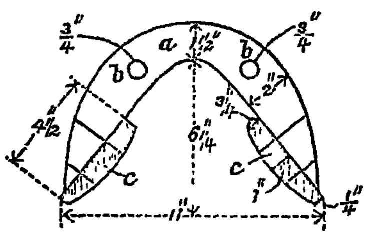


FIG. 2.

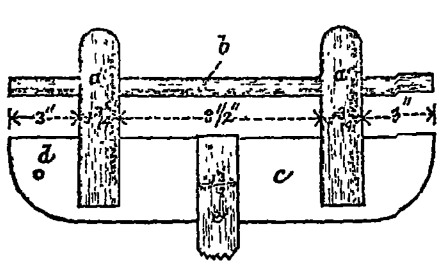


Figure 1 is a front elevation, and figure 2 a side elevation of a saddle for a fuel-carrying mule. The two curved pieces a, a *are made of oak, the cross pieces* b, b *of some tough wood, while the flat pieces of wood* c, c *are of fir. Ropes passing through the holes* d, d *go under the mule's tail. The leather girth* e, *which keeps the saddle in position, passes over the flat pieces of wood and round the animal's body. (Scale = 1/8.)*

The saddle rests on a large padded quilt or on a saddle-cloth consisting of two or three blankets thrown over the animal's back, and sufficiently large to prevent its flanks from being rubbed.

This pad is kept in position by cotton straps passing round the animal's hind quarters and chest. The pad is 3 feet long and is generally furnished with a leather covering to keep it dry in wet weather.

A hole is cut in the pad to ease the shoulders of the pony or mule. The saddle is kept in position by means of a leather girth which passes over the flat pieces (*c*, *c*) and round the animal's body. Iron rings are attached to either end of the girth, which is tightened by bringing the two rings together and fastening them with a leather thong. A crupper, padded where it passes under the animal's tail and attached to the saddle, prevents it from slipping forward.

The firewood is cut up into billets 2 feet long, and these are fastened by cords to the saddle; the cords pass over the rods *b*, *b*. The load is equally balanced on either side of the animal. A pony or mule will carry 2 maunds (164 lbs.) of firewood.

Fuel is often carried on ponies, mules and bullocks without any saddle, or at most a narrow curved pad (see § 7, page 10) placed so as to protect the backbone. The ropes which are passed round the fuel are laid on some cloths thrown over the animal's back or the narrow pad above referred to. This system cannot be too strongly condemned, as the backs and sides of the ponies or mules soon become quite raw.

Where saddles are used, heavier loads can be carried, and this with far less injury and cruelty to the animals themselves. Sleepers or short scantlings can be fastened to the saddle with ropes in the same way as the firewood is attached to it. The same number of sleepers should be put on either side.

§ 9. Bullocks and Buffaloes.—In the plains and fairly flat country, bullocks and buffaloes, besides being used for hauling carts, are also employed to drag bamboos, poles and scantlings out of the forests to the market or to the nearest cart-road. A cloth is thrown over the animal's back and a small

saddle made on the same principles as that shown in figures 1 and 2 (page 11) placed on it to prevent it from being rubbed, and the poles or bundles of bamboos are fastened together by a short piece of cord, which passes over the animal's back, so that the upper ends of the poles or bamboos fall on either side of the shoulders of the animal, and the lower ends rest upon the ground. *Bhabar* grass neatly arranged is hung across the animal's back to protect its sides.

In the Anamalais Hills (Madras Presidency) two bullocks are yoked together as for a cart, and one end of the log is tied to a rope which is attached to the yoke; the rope is long enough to keep the log behind the bullocks' heels: but coming down steep slopes the log often gets out of control, charges down, and accidents are common. The logs could be kept under control if krempes (see page 183) were used.

For poles a yoke is also used. The poles are tied tightly together at one end, and this end is tied close up to the yoke. The back ends of the poles drag loosely on the ground; as many as fourteen good-sized poles may be taken out by one pair of bullocks.—(*Mr. F. A. Lodge.*)

In the Chhatisgarh district (Central Provinces) bamboos and small poles are dragged out by a pair of bullocks or buffaloes, an ordinary yoke being used, and the thin ends of the bamboos or poles being tied together in a bunch and bound under the yoke in precisely the same way as are the shafts of a cart. The thick ends of the poles drag along the ground.—(*Mr. A. W. Blunt.*)

§ 10. CAMELS.—The camel is used in the drier parts of the Punjab, Rajputana and north-western parts of India as a beast of burden. The saddle resembles somewhat an ordinary horse-collar in shape and is placed over the hump of the animal. The saddle consists of two pads made of country cloth and stuffed with grass. The ends of the pads are brought close together, and a knee-shaped stick is placed in them and fastened to them. Two pieces of wood, placed crosswise, forming a rough saddle-tree, are fastened over the other ends of the pads which are thus kept slightly apart; some small rods are placed on the

upper side of the pads, passing under the cross-shaped saddle-tree, and are tied to the pad near the other end, thus stiffening the saddle. The saddle fits over the hump of the camel and is kept in position by a slight band passing under the animal's body. A rough crupper passing under the animal's tail is fastened to the back of the saddle to prevent it from slipping forward when going down hill, and a band passing round the animal's neck and fastened tightly to the front of the saddle keeps the load from slipping back when the animal goes up hill.

In the Punjab, rough panniers made of branches of *jál* and *farásh* are used for the carriage of fuel in the Montgomery Forest Division.

The following information with regard to the use of camels for the transport of fuel has been kindly communicated by Mr. C. Rossiter, Extra-Assistant Conservator of Forests, Punjab.

" A camel can walk about 10 miles a day, but must be allowed to rest every fourth day. It can carry about 14 cubic feet stacked of dry *jhand* fuel, which is equivalent to about 5 maunds or about 400 lbs. Camels cannot be used on slippery ground; and must be worked at night as soon as the weather becomes hot. A camel, with *kajawas* (panniers), occupies about 8 feet of space laterally, but as it never walks straight, roads for the use of camels must be made about 12 feet wide.

Camels work well during the cold weather months, and although they can carry loads for a greater distance than 10 miles, it is not advisable to make them do so, as they will break down if worked too hard. Two or three men working together can load and look after from 10 to 18 camels. Camels are trained to carry light loads after they attain their third year. They are in their prime at 8 and work till about 20 years old, if properly looked after. In the Punjab they cost from R60 to R90 each when in good working condition, but it will always be cheaper to hire them when required. In the Montgomery District, Punjab, R1 to R1·5 is paid per 100 cubic feet stacked per march of from 7 to 10 miles."

§ 11. CARTS.—Wherever cart-roads exist and carts and fodder for the animals are available, or in places where the ground is sufficiently flat to allow of carts entering into the forests in all directions without made roads, the carriage of timber or firewood by carts is much cheaper than by the agency of men or pack animals. Logs, scantlings of all kinds, poles and firewood may be carried in ordinary carts. Carts specially constructed for the carriage of large logs are not as a rule necessary. The common country cart varies considerably in shape and size in the different parts of India; the construction of the common country cart of Northern India is shown in figures 3 to 6 (pages 16, 17, 18)

§ 12. The following description of the country cart shown in figures 3 to 6 was written by Rai Saheb Upendra Nath Kanjilal, Extra-Assistant Conservator of Forests, and Vernacular Instructor at the Imperial Forest School, Dehra Dun:—

"*The shafts a, a* (fig. 3, page 16) are 12' 9" long and 3½" × 2" and are made of sāl (*Shorea robusta*). They are not parallel to each other, but meet at the front where the yoke is attached. The back ends are slightly bent upwards, so as to prevent the load from slipping off behind. The shafts fit into two square notches about half an inch deep, cut in the axle (see fig. 4, page 16), to which they are simply tied by ropes (they are neither nailed nor bolted to it). At the front end the shafts are bevelled on the inner sides, and are nailed to a wedge-shaped piece of wood (*b*) which is placed between them. An L-shaped elbow (*c*) (fig. 5, page 17) is bolted on to this wedge-shaped piece of wood and keeps the ends of the shafts off the ground when the bullocks are unyoked.

Body of the cart.—Five cross-pieces of sāl (*d, d*) (fig. 3), 4½ to 5 inches wide and 2 inches deep, and of lengths varying with the distance between the shafts, are nailed on to the shafts, at intervals of from 15 to 23 inches. Pieces of plank (*e, e*), usually rejected slabs of trees, are placed between these cross-pieces. Battens are placed over them and sometimes nailed to the shafts. Two other pieces of wood (*f, f*) 6 feet long and 3 inches by 2 inches, are also nailed to the shafts, and are necessary to keep the wheels in position. Two holes (*g, g*), one near either end, are bored in each of the cross-pieces, and removable uprights (*h, h*) (see fig. 5, page 17) usually 3 feet long, are placed in these holes. After the cart is loaded, each pair of uprights are tied together by ropes. The length of the uprights used varies according to the nature of the load of the cart.

The axle *i* (fig. 4, page 16) is also made of sāl, is circular in section, 6 feet long and 5 inches in diameter. About 1½ feet from either end the diameter is reduced to 2½ inches, so that it may fit into the hole in the nave of the wheel prepared to receive it. The thickness of the axle is reduced in two steps

FIG. 3.

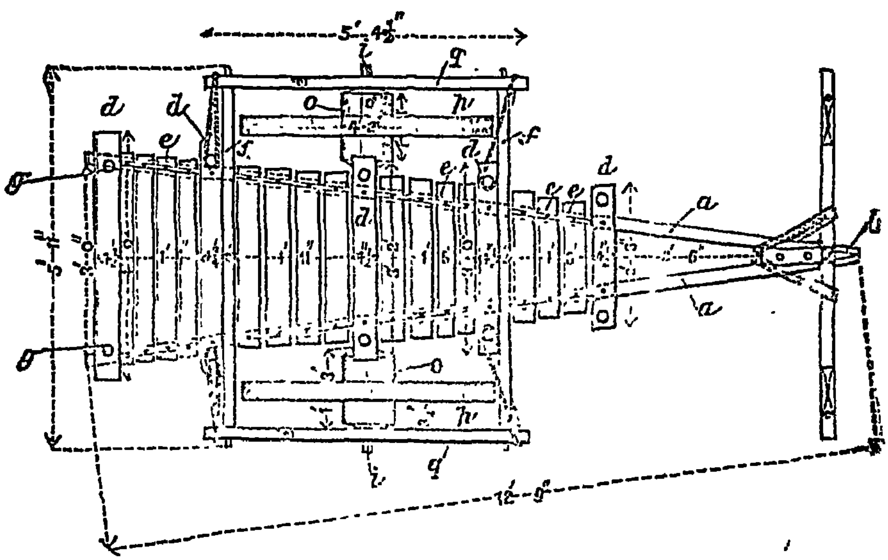


Figure 3 is a plan of a country cart of Northern India: a, a *are the shafts;* b *a wedge-shaped piece of wood;* d, d *cross-pieces nailed to the shafts;* e, e *planks forming the bottom of the cart;* f, f *cross-pieces which help to support the wheel;* g, g *holes in cross-pieces, into which the uprights* h, h *(fig. 5, page 17) are fitted;* i, i *are the ends of the axle;* o *is the nave;* p *the rim of the wheels;* q, q *are the pieces of wood which keep the wheel in position Scale 3 feet = 1 inch.* (*Drawn by Rai Saheb U. N. Kanjilal.*)

FIG. 4.

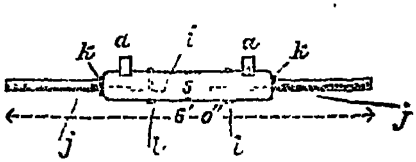


Figure 4 is an elevation of the axle of the common country cart of Northern India; i *is the axle, 5 inches in diameter at mid length and* j, j *bars of iron let in to strengthen the journal;* k, k *wrought iron rings shrunk on to prevent the axle from splitting;* a, a *the shafts seen in cross section;* l, l *the bolts which fasten the iron bar to the axle. Scale 3 feet=1 inch.* (*Drawn by Rai Saheb U. N. Kanjilal.*)

and by easy curves of ¾ inch radius, instead of rectangular incisions; on the first step ⅜ inch deep a wrought iron flat bar ring *k, k,* (1"×⅜") is shrunk on to prevent splitting and also abrasion by the rotating wheel.

On the lower face of the journal is let in a half-round bar of wrought iron (*j*, *j*) about 2 inches wide and 1 inch thick, this bar is sunk into the middle portion of the axle for a length of about 24 inches and is bolted by wrought iron 3-inch bolts passing through the mid length of the axle and bar from top to bottom. The bar strengthens the journal end and prevents abrasion of its underface.

The wheels.—The felloes (*m*, *m*) (fig. 5, below) are 9 inches deep and 3½ inches wide, and are made of sissu (*Dalbergia Sissoo*). The spokes (*n*, *n*) are of sál (*Shorea robusta*) and vary in section from 4 inches by 2 inches to 2 inches square. There are six parallel pairs of spokes in each wheel. The first pairs put in (parallel to the diameter of the wheel) are of the largest scantling. The next pairs are of medium size and are tenoned partly into the nave and partly into the spokes already in position (see fig. 5 below). The last pair of spokes are of the smallest scantling. All the spokes (except the first pairs) are mortised partly into the nave and partly into the spokes last placed in position.

FIG. 5.

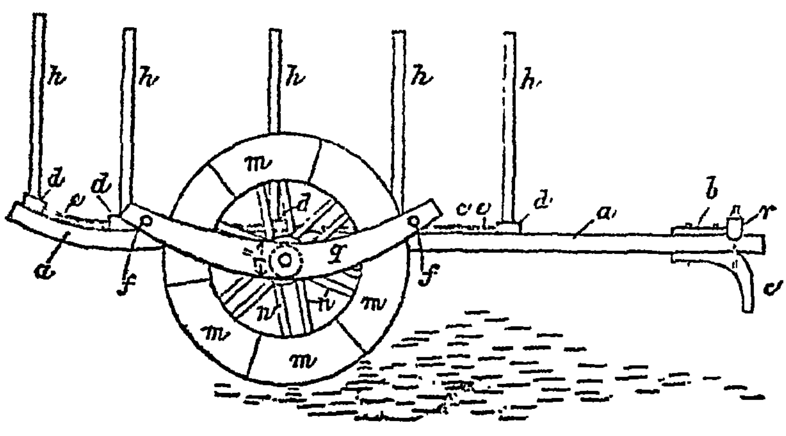


Figure 5 is a side elevation of the common country cart of Northern India; a *is the shaft;* b *the block of wood to which the shafts themselves and the knee piece* c *are bolted;* d, d *are the cross-pieces into which* h, h *the uprights are stepped;* e, e *are the planks which form the bottom of the cart;* f, f *are the ends of the cross-pieces on to which the keeper* q *is fitted;* m, m *are felloes of the wheels, and* n, n *its spokes;* r *is the yoke. Scale 3 feet = 1 inch.* (*Drawn by Rai Saheb U. N. Kanjilal.*)

The nave (*o*) (fig. 3, page 16) is of sál (*Shorea robusta*) slightly bevelled at either end. Each end of the axle hole is lined with a wrought

iron ring 1 inch wide and ¼ of an inch thick rounded off on the inner face to ¾" radius; a wrought iron ring with a diameter of 5 inches is shrunk on over the body to further strengthen it. The extreme length of the nave is 15 inches and its diameter is 10 inches, the diameter of the axle hole being 2½ inches.

The wheels are kept in their places by two curved pieces of wood (*q, q*) (fig. 5), 7 inches wide at the middle and 4 to 5 inches wide at the ends. These pieces of wood are 2 inches thick and 5 feet long. They are fitted on at mid-length to the journal ends, and at their ends on to the two long cross-pieces (*f, f*) (fig. 3, page 16) which are fastened to the body of the cart itself, and are tied to the nearest upright or to the shafts. In order to take a wheel off, the ends of this curved keeper are untied, and the keeper itself removed. The wheel is then pulled off. The operation is much facilitated by tilting the cart slightly so as to take the pressure off the wheel. The keepers (*q, q*) serve as foot-rests for men when loading or unloading the cart.

The yoke (*r*) (fig. 6) is made of sissu (*Dalbergia Sissu*) if available, but can also be made of sàl (*Shorea robusta*). It fits into a notch cut in the front ends of the shafts, and is fastened to the latter by ropes. It is 2¾ inches thick with a maximum width of 4 inches, and is rounded where it rests on the necks of the cattle.

FIG. 6.

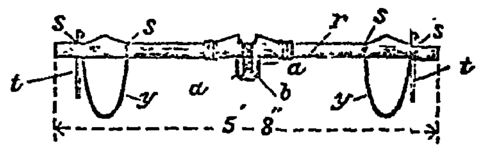


Figure 6 is an elevation of the yoke of the common country cart of Northern India; r *is the yoke;* b *the block of wood (end of it) and* a, a *the ends of the shafts which are nailed to it;* s, s *are the vertical holes bored in the yoke to take the pins* t, t. *Scale 3 feet = 1 inch. (Drawn by Rai Saheb U. N. Kanjilal.)*

Four vertical holes (*s, s*) are bored through it, one on either side of the portions which rests on the necks of the cattle. Wooden pegs (*t, t*) to which the halters of the cattle are fastened fit into these holes. Usually only two pegs are put into the two outer holes, and the ends of the halters are passed through the other two holes and tied in a knot."

§ 13. When it is required to place a large log in a country cart, one wheel is usually taken off, the bared journal end placed on the ground and the sticks which form the side of the cart removed. A rough inclined plane of logs is formed on either side of the axle and the log rolled up this inclined plane on to the body of the cart by means of ropes, and poles used as levers.

The mid-length of the axle should be supported during this operation, the cart and its load should not be carried on the journal end alone.

The log is tied to the body of the cart with ropes, or held while the axle of the cart is brought into a horizontal position by levers, when the wheel is replaced.

When the log is too heavy to be placed on the body of a cart, it may be slung by chains underneath one or two pairs of wheels, the log being fastened below the axles of the wheels so as to raise it slightly above the ground.

A cart which is intended to carry heavy logs slung below its axle should have larger wheels. If the cart is constructed with long shafts and a short tail, 2 or 3 men can use the cart itself as a lever to raise a heavy log off the ground to the height of the axle to which it is to be attached with chains. In the Andamans squared logs of padauk up to 3 feet side and weighing as much as 3 tons were thus raised by 4 or 5 men and slung below the axle. The wheels were specially made 7 feet 9 inches in diameter. Buffaloes were used to drag them over good roads. The axles of the carts were of iron.—(*Mr. E. G. Chester.*)

§ 14. The following descriptions of the timber carts in use in Upper Burma have been compiled from drawings and descriptions kindly sent by the Bombay-Burma Trading Corporation; Messrs. Darwood & Sons, timber contractors; Mr. J. Oliver, Conservator of Forests; and Mr. C. E. Muriel, Deputy Conservator of Forests, Eastern Circle, Upper Burma.

In Upper Burma teak logs are now usually transported on

(1) ordinary country carts,

(2) small timber carts (Burmese *gindeiks*).

In both country timber cart and small gindeik the logs are placed on the body of the cart above the axle.

Ordinary country carts can carry logs up to 6 to 7½ feet girth, while the small timber cart will carry logs up to 9 feet girth; the former dragged by buffaloes, the latter by buffaloes or an elephant.

§ 15. THE ORDINARY COUNTRY TIMBER CART.—The Burmese country timber cart consists of a pair of wheels, a wooden axle, two wooden shafts, a yoke and a simple framework which supports the log.

In Upper Burma the ordinary Burmese cart-wheel (*padaung*) consists of four pieces of wood—

(1) The axle-box, which consists of a hollow cylinder 15 inches long, 4½ inches outside and 3½ inside diameter. It is usually built up of two pieces of wood bound together by plaited cane bands.

(2) The middle piece (*klema*), which is a slab of wood 3 feet 6 inches in length, 1 foot 8 inches wide and 4½ inches thick, tapering to 2 inches at the edges.

(3) & (4) Two side pieces (*satkwe*) of constant width and fastened to the central slab by wedge-shaped tongues of wood (dowels) inserted in slots, cut in the thickness of the wood, for their reception.

The middle and two side pieces are usually made of padouk (*Pterocarpus indicus*). In order to give greater rigidity to the wheel, *two* pieces of stiff bamboo are placed one on either side of it and tied together by pieces of cane passing through holes cut in the outer slabs of which the wheel is made.

The wheels are round at first, but soon wear oval, as the wood wears quicker with the grain than against it. The natives prefer them to English wheels, as they travel better through deep mud. Municipalities and the Public Works Department object to them, as they cut up the roads very much. They are rapidly going out of use in the more civilized parts of Burma.

In the Pyinmana district the cart now generally used by the Bombay-Burma Trading Corporation is the common country-cart fitted with wheels of the English pattern, instead of the old-fashioned solid Burmese wheels. The wheels only are supplied by the Corporation to their contractors, and the remaining parts of the carts are constructed locally in the forest without using any iron work whatever; consequently if any part breaks down, it can be at once repaired on the spot

The cart thus modified consists of the following parts :—

(*a*) A wooden axle.

(*b*) A pair of wheels.

(*c*) Two shafts.

(*d*) A wooden yoke.

(*e*) The framework of the cart.

(*a*) The *wooden axle* (fig. 7, below) is usually made of *Schleichera trijuga* and is 7 feet long. The central portion of this axle is rectangular, 3½ feet long, 7 inches wide, and 9 inches deep. Two semi-circular grooves (*c, c*), 3 inches in diameter, are cut on this portion on either side of the axle at a distance of 14 inches from its centre The two ends (*b, b*) are each 21 inches long, circular in section, and tapering slightly outwards, the diameter of the inner end of these portions being 3½ inches, and the diameter at the outer end 2½ inches.

FIG. 7

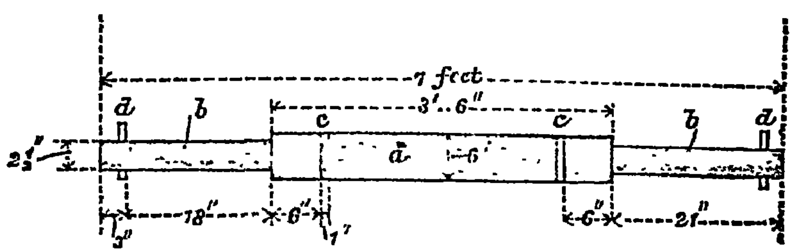


Figure 7 is an elevation of the axle of the common Burmese country timber cart ; a *is the central portion of the axle, rectangular in section ;* b, b *are the journal ends, which are circular in section ;* c, c *are grooves which help to fix the body of the cart on to the axle ;* d, d *are the linch pins which keep the wheels in position.* (*Scale 2 feet = 1 inch.*)

A small rectangular hole (*d*), 1⅛″ × ⅜″, is bored in each axle at a distance of 2 inches from the end to take the wooden linch-pin which keeps the wheel in position.

(*b*) The *wheels* (figs. 8 and 9, page 23) are 4 feet to 4 feet 2 inches in diameter. The nave (*a*, fig. 9) is made of padouk (*Pterocarpus indicus*, Willd.), is circular in section and 18 inches long, and contains an iron axle-box. The middle portion of the

nave into which the spokes are tenoned is 10 inches in diameter and 8 inches long. The spokes are 3 inches wide, and consequently a 2½-inch space is left on either side of the spokes on this central portion of the nave, after they have been put in position. The outer diameter of either end of the nave is 8¾ inches, so that its exact shape is that of a short cylinder, with two ends in the shape of truncated cones. A hole (*e*, fig. 8), 4 inches in diameter, is bored in the nave to receive the iron axle-box. The nave is strengthened by four wrought iron rings (*f*, *f*, fig. 9), 1 inch wide and ⅜ths of an inch thick. Two of these are placed, one at either end, while the remaining pair are placed round the central portion of the nave, one on either side of the spokes.

The nave is connected with the rim of the wheel by 14 teak-wood spokes (*b*, *b*, fig. 8, page 23); two spokes being let into each felloe (*c*, *c*, fig. 8). The spokes are 16 inches long (from nave to felloe), 3 inches thick, and 2½ inches deep. They taper from 3½ inches at the nave to 2½ inches at the circumference of the wheel. They are tenoned both into the nave and the felloes.

The rim of the wheel consists of seven teak-wood felloes (*c*, *c*) which are each 21 inches long, 4 inches deep, and 3 to 2½ inches wide. These are dowelled into each other in the usual manner, and are further strengthened by an iron tyre (*d*, fig. 8), 2½ inches wide and half an inch thick. This tyre is 12½ feet in circumference, and should be heated, put on to the rim of the wheel while hot, and then cooled by pouring cold water over it or immersing the wheel in water. In cooling, the tyre shrinks and so tightens all the joints between the felloes.

(*c*) The *shafts* are made of roughly rounded poles of any kind of tough wood. A cart has two shafts which are united at the end to which the yoke is attached. The length of the shafts from the axle to the front end is about 13 feet for buffaloes and somewhat less for bullocks. The shafts project backwards about 2 feet beyond the axle which gives them a total length of about 15 feet. They are 5 inches in diameter. The way in which the shafts are attached to the axle of the cart is shown in figures 10, 11 and 12, pages 24 and 25. Two holes (*c*, *c*, fig. 12)

FIG. 8.

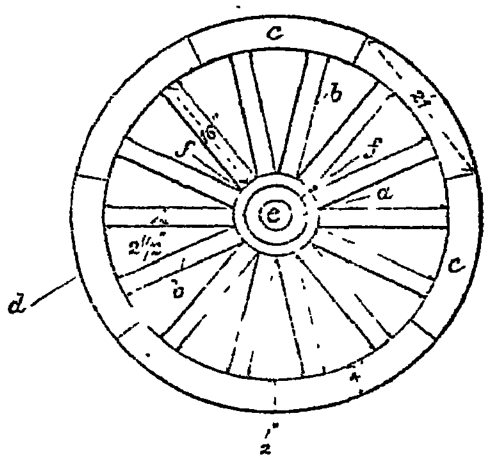


FIG. 9.

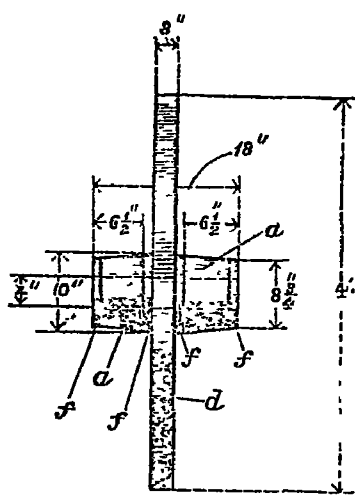


Figure 8 is a front elevation and figure 9 a side elevation of a wheel of a timber cart; a *is the nave;* e *is the hole bored through the nave and lined with an iron tube to take the axle;* b, b *are the spokes;* c, c *the felloes which make up the rim of the wheel;* d *the iron tyre;* f, f *iron straps added to strengthen the axle-box. (Scale 2 feet = 1 inch.)*

are bored through each shaft at a distance of 6 inches from each other. Four wooden pins (two in each shaft) about 3 feet long and 2½ inches by 1½ inches in section (*d*, *d*, figs. 10 and 12) are placed in these holes. The lower ends of these pins fit into grooves (*c*, *c*, fig. 11) cut on either side of the axle *f* to receive them, while the upper ends project above the body of the cart (Burmese *sin*), and are firmly tied together with ropes (*g*, fig. 12) made out of bamboo.

FIG. 10.

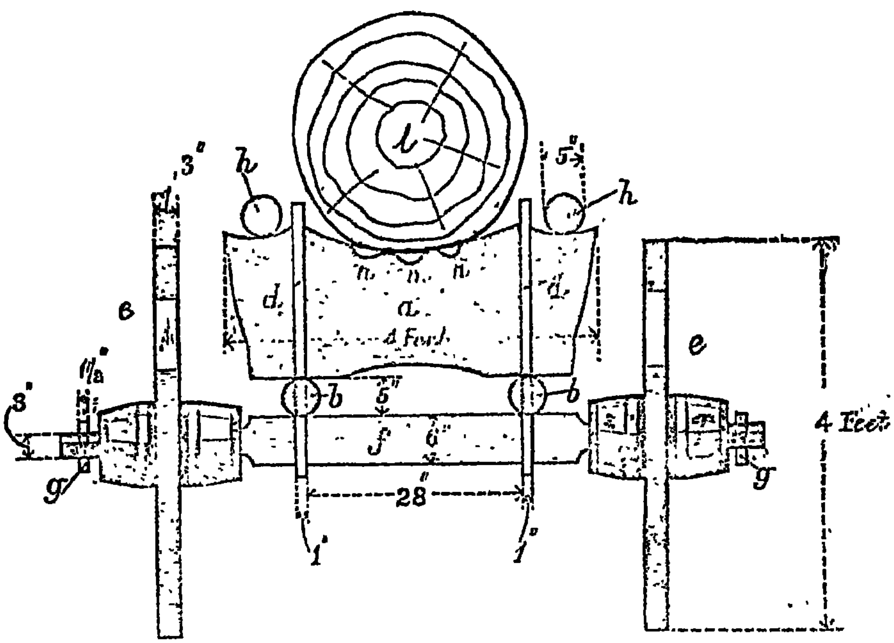


Figure 10 is an end sectional elevation of a Burmese timber cart with a log on it, a *is the body of the cart,* b, b *the two shafts, seen in cross section;* d, d *the pins which fix the body to the axle-tree* f; c, c *are the wheels,* g, g *the linch-pins;* h, h *the levers seen in cross section, used for getting the log on to the cart;* n, n, n *the notches under the log in which cross bars are placed to effect the final adjustment of the log on the cart;* l *is the end elevation of the log. (Scale 2 feet = 1 inch.)*

FIG 11.

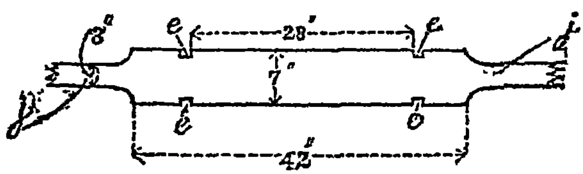


FIG. 12.

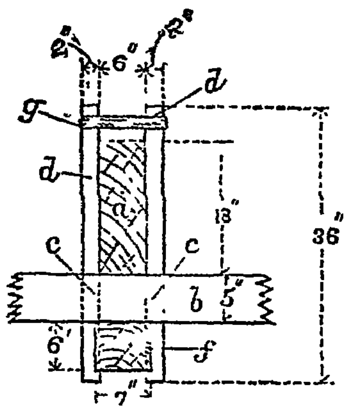


Figure 11 is a plan of part of the axle-tree f *(fig. 10) to show the position of the notches* e, e, e, e, *in which the pins* d, d *fit;* j, j *are parts of the journals of the axle, on which the wheels revolve.*

Figure 12 is a cross-section through the body of the cart; a *is the body of the cart in cross-section;* b *is part of a shaft;* c, c *the holes in the shaft through which the pins* d, d *pass;* f *is the axle-tree seen in cross-section;* g *the cords by which the upper ends of the pins are fastened together. (Scale 2 feet = 1 inch.)*

The distance between the shafts where they are fixed to the axle is about 2 feet. The shafts meet in front for a length of 12 inches and are usually tied together and to the yoke by means of strips of raw hide or pieces of cane.

(*d*) The *yoke* is made out of teak. It is 6½ to 7 feet long, and shaped as shown in figures 13, 14 and 15. It is placed on the necks of the buffaloes or bullocks. The latter are yoked to the cart by pegs passing through the yoke and falling on either side of the animal's neck; a loop of raw hide or string passes from one peg to the other under the animal's neck.

FIG. 13.

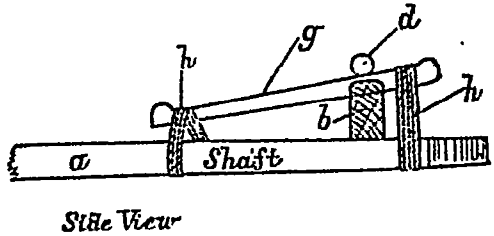


FIG. 14.

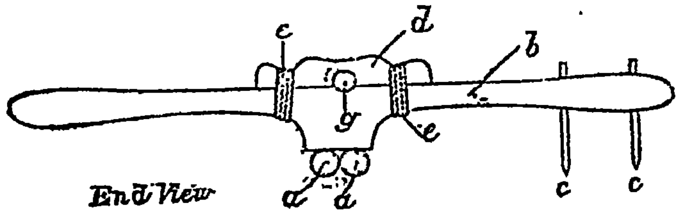
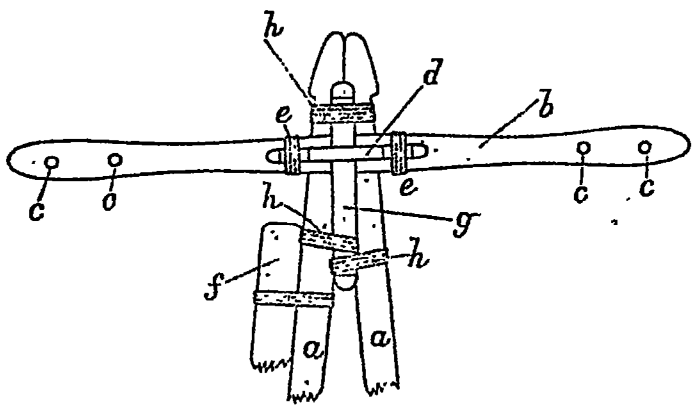


FIG. 15.



Figures 13, 14 and 15 show the method of fastening the yoke to the shafts of a common Burmese country cart. Fig. 13 is a side elevation, fig. 14 a front elevation, and fig. 15 a plan. In these figures a, a *are the shafts;* b *the yoke;* c, c *the pins which fall on either side of the buffaloes' neck, or the holes in which these fit;* d *the piece of wood to which the yoke is tied by the cords* e, e *;* g *the piece of wood, tied to both shafts by the cords* h, h, h, *passes over the yoke* b *and under the piece of wood* d *;* f *is the end of one of the levers used in raising the log on to the cart. Scale 2 feet = 1 inch. (Drawn by Mr. J. W. Oliver.)*

(*e*) The *framework* of the cart (fig. 10, page 24) (Burmese *sin*) consists of a block of pyinkado or teak 4 feet long, 18 inches deep, and 6 inches wide.

This block is placed above the shafts and is kept in position by the pins (*d, d*) which pass through the shafts (*b, b*) and fit into the two grooves cut on either side of the axle (e, e, e, e, fig. 11). This block forms the body of the cart, and the log rests partly on it and partly on the shafts.

The levers used for finally adjusting the log are placed in the grooves (*n, n, n*, fig. 10) cut on the upper surface of the block.

§ 16. Elephants, buffaloes, or bullocks may be used to drag this kind of timber cart. When elephants are used, so long as the ground is level, the log is balanced in the ordinary way; but when the logs have to be carted down an incline, the log is placed in the cart with the heavier end of the log resting on the ground behind; on coming to level ground, the log is again shifted into its original position.

§ 17. METHOD OF LOADING THE CART.—In the Pyinmana district the method of loading the cart is as follows :—

Two long poles (*h, h*, fig. 10) to serve as levers are placed on the top of the *sin*, (*a*, fig. 10) resting outside the pegs (*d, d*, fig. 10). The levers project some 3 or 4 feet beyond the wheels and are tied at their further extremities to the shafts near the yoke. The cart is then placed with the levers over the end of the log to be lifted (see fig. 16, page 28), and the front of the cart lifted till the levers touch the ground. A chain is then passed under the end of the log and attached to the levers.

Blocks having been placed against the wheels, the yoke is drawn down by six or seven men until it rests on the ground. This has the effect of raising the log; props are then placed under the log, and the process, if necessary, is repeated. When the log is sufficiently raised, the cart is backed under it, as far as it will go, and the props and levers are removed. Buffaloes are next harnessed to the end of the log which is then pushed by them on to the cart as far as is necessary.

FIG. 16

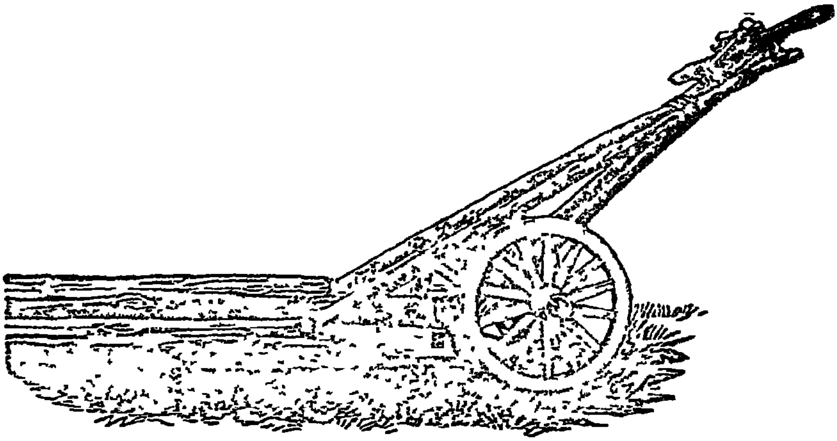


Figure 16 shows a teak log in process of being lifted on to a cart; a, a *are the long levers tied to the front end of the shafts and resting on the body of the cart outside the pins, by means of which the end of the log is raised off the ground. (From a photograph taken by Mr. J. W. Oliver, Conservator of Forests.)*

The final adjustments as regards balance are made by means of iron crowbars inserted in grooves (*n, n, n,* fig. 10, page 24) of the *sin*, and the log is then secured in this position.

The thin end of the log, it should be noted, rests over the yoke of the cart, the heavy end being placed aft. The log is then tied in position and is ready to be carted away. The carting is generally done by one pair of buffaloes, but more can be employed if necessary.

Six or seven men are required to load a log, but as there are always several carts together, it is not necessary to employ more than one man to each cart.

The log, part of which is seen in figure 16, in process of being loaded, was 32 feet long and 5 feet in mean girth. The largest log brought out in this manner was 24 feet long with a mean girth of 10½ feet. If the logs to be carted are not very large, shorter levers can be used. In this case the

levers are tied to an iron crowbar placed under the shafts, notches being cut on the levers to prevent their slipping.

§ 18. In the Shweli forests, where country timber carts with solid wheels are still in use, the log is first dragged by buffaloes or an elephant to the cart-road. Four or five pairs of buffaloes are sometimes required to drag a heavy log. The middle pairs are attached to ring-bolts screwed into the log. Occasionally a mixed team of an elephant and buffaloes is used. Buffaloes cannot be employed on very broken ground. They can drag logs up very steep hills, but require a broad even track.

The log is placed on the cart as follows. Inclined grooves for the wheels of the cart are cut in the ground, and the cart is backed into the grooves so that the axle rests on the surface of the ground; the log which has been previously placed in position is then pushed over rollers on to the cart by means of an elephant or a pair of buffaloes. When loaded, the log should be so balanced that the hinder (butt) end just drags on the ground.

Either an elephant or buffaloes can be used for dragging this cart. If the latter, two or more pairs are required, one pair being harnessed to the butt end which is thus kept slightly off the ground. If an elephant is used, the end of the log is allowed to drag along the ground, and the animal is hitched on to a hook at the end of the pole of the cart.

§ 19. Carts are loaded in the Tharrawaddy district in the following manner. Two upright poles with a fork at the top of each are planted in the ground about 6 feet apart. A loose cross-piece rests in these forks. One end of a chain is fixed to the centre of this cross-piece, and a two-handed lever is attached to the same point. The log is then placed between the uprights, and the other end of the chain passed under it and securely fastened to the cross-piece above. The two-handed lever is now rotated round and round at right angles to the cross-piece and the chain is thus wound round and round the cross-piece and the log raised so that a cart can be pushed under it.

In the Lower Chindwin district this principle of lifting logs has been still further developed. A light portable wooden frame, consisting of two strutted posts supporting a cross-piece, is substituted for the framework of rough poles used in the Tharrawaddy district.

An iron screw, about 2 inches in diameter and 4 feet long, works through a hole cut in the cross-piece near its centre, in a socket fixed to the upper surface of this beam. The posts of the framework are about 6½ feet high. The lower end of the screw terminates in a swivel ring, through which a chain can be slung.

Just above the ring four iron handles project from the screw, like the moveable levers from a capstan-head, and by these the screw is rotated and thus raised. When the log, which is slung by a chain passed round it somewhere near its centre of gravity to the swivel ring, is sufficiently raised off the ground, by rotating the screw, a *gindeik* (see page 19), with low broad solid wheels, is placed near the end of the log resting on the ground, and a man gets on to the end of the log which is in the air and by his own weight raises the end near the cart, which is then pushed along under the lifted log to the required position.*

§ 20. SMALL GINDEIK.—The small *gindeik* consists of the following parts:—

(*a*) An axle.
(*b*) A pair of wheels.
(*c*) A shaft.
(*d*) A wooden yoke.
(*e*) The body of the cart itself.

The *axle* is made of iron and is 6 feet in length. The central portion is 4 feet long, rectangular in section, being 3 inches deep and 1¼ inches thick, of the shape shown in figure 17.

The ends (*b*, *b*) of the axle are circular in section with a diameter of 2¾ inches at the inner end, tapering to 2½ inches at the outer end. They are 12 inches long; slots 1 inch by ⅝ inch are cut at a distance of 2 inches from either end to receive the iron linch-pins (*c*, *c*), which keep the wheels in position.

* The "Indian Forester," June, 1897.

FIG. 17.

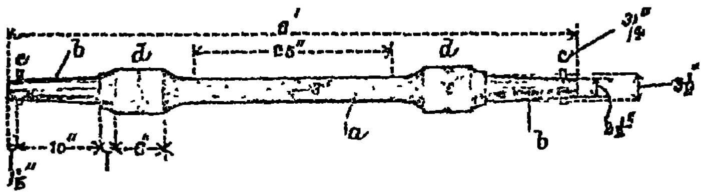


Figure 17 is an elevation of the iron axle of the small Burmese timber-cart (gindeik); a *is the central portion of the axle, rectangular in section;* b, b *the two journal ends on which the wheels rotate are circular in section;* d, d *are the rectangular holes punched in the axle to receive the bolts which fasten the body of the cart to the axle;* c, c *are the pins which keep the wheels in position.* (*Scale 2 feet = 1 inch.*)

The *wheels* are constructed similarly to those described on page 21, *et seq.* They are only 3 feet 8 inches in diameter, but have wider tires and are generally heavier, and in consequence better suited for rougher roads. The nave is made of padauk, is 10 inches long, 10 inches in diameter at the middle and 8 inches at either end, the axle-pin ¾ in diameter. There are four iron rings—two are placed, one on either side of the spokes; and the other two, at either end of the nave. These rings are 1¼ inches wide and three-eighths of an inch thick. The spokes are generally made of pyinkado (*Xylia dolabriformis*); they are 12 inches long, 3 inches wide, and 4 inches deep. The rim of the wheel is made up of five pyinkado felloes, each 23 inches long, 4½ inches deep, and 5 inches wide. An iron tire, 11 feet in circumference, 5 inches wide, and ½ inch thick is shrunk on to the rim.

The *shaft* is generally made of pangah (*Terminalia Chebula*) and is 15 feet long, 7 inches deep, and 6 inches wide at the larger end; and 4 inches wide and 4 inches deep at the end to which the yoke is attached. An iron strap (*b*) (fig. 18, page 32) 2½ feet long, 2 inches wide and half an inch thick, is passed round the small end of the shaft and fastened to it by three bolts, five-eighths of an inch in diameter, one of which is an eye bolt. An iron loop, (*e*), three-fourths of an inch in diameter, is

welded on to the upper side of this stirrup, at a distance of 3 inches from the end of the shaft. The eye bolt (*d*) is about 20 inches distant from this loop. A strong ring-bolt (*f*) passes through the eye bolt (*d*) and is furnished with a two-armed nut (*g*) which can be screwed up or down at will.

FIG. 18.

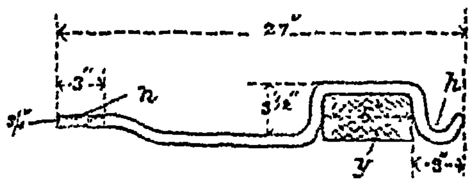
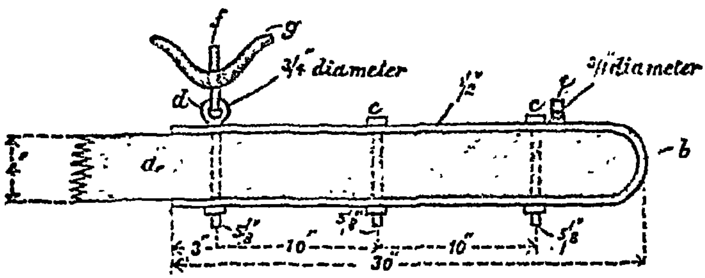


FIG. 19.



Figures 18 and 19 show the device for attaching the yoke to the shaft of a timber-cart. Figure 19 is an elevation of the end of the shaft; a is the shaft; b is the stirrup strap; c, c, the bolts by which the stirrup is fastened to the shaft; d is an eye bolt; e is a loop welded on to the strap; f is a ring-bolt passing through the eye bolt d; g is an armed nut working on the stem of f.

Figure 18 shows the bar which fits on to the stirrup strap b and keeps the yoke in position; n is a slot cut in the end of the bar which fits on to the stem of the ring-bolt f (fig. 19); y is the yoke in cross section; h is the hook which fits into the loop e. (Scale 1 foot = 1 inch.)

A wrought iron bar, 2 feet 3 inches long, 3 inches wide, and three-fourths of an inch thick, of the shape shown in figure 18, furnished with a slot *n* at one end, has a strong hook, *h*, at the other. This hook is placed in the loop *e*, near

the end of the stirrup strap *b*. The yoke is placed in position up against this loop, the bar placed over it, and the ring-bolt *f* is placed in the slot at the end of the iron bar. The nut is then screwed on tight so as to keep the bar fixed in position. This fastening may be further strengthened by passing a chain round both shaft and yoke, the end link of the chain being placed over the ring-bolt. The wooden yoke used is similar to that already described.

A block of pyinkado (*b*, figs. 20, 21 and 22) 4 feet long, 15 inches deep, and 12 inches wide forms the *body* of the cart. A segmental trough, 24 inches wide, with a maximum depth of 5 inches, is cut centrally on the upper surface of this block to receive the log (see figs. 20, 21, 22).

Two curved iron bars (*d*, *d*, figs. 20, 21, 22), 3 inches wide, ½ inch thick, and 4 inches shorter than the *upper surface* of the block, are fastened with stout iron spikes on to it along either side to prevent the edges of the block being damaged by the log.

A notch, the same dimensions as the axle and rectangular in section, is cut in the lower side of the block, to receive the axle. The axle is kept in position by two iron plates (*h*, *h*, figs. 20, 21 and 22) which are spiked on to the bottom of the body of the cart.

A hole, 1 foot long, 3½ inches deep, and 8 inches broad, is cut in the block to receive the end of the shaft (*a*, fig. 21) which is bolted to the axle.

Two bent iron stays (*c*, *c*, figs. 20 and 22) are placed one on either side of the shaft, and are bolted to it and to the block of pyinkado in order to strengthen the connection. The straight portion of the stay is 24 inches long and the bent portions each 3 inches. The width of the stays is 2½ inches and their thickness ½ an inch.

Two strong curved pins (*k*, *k*, figs. 20, 21 and 22) are bolted through the body of the cart, and the chain which keeps the log in position in the cart is fixed to them.

The advantage of the small gindeik over the cart described in § 15, pages 20 to 27, is that it can be used on much rougher

FIG. 2 .

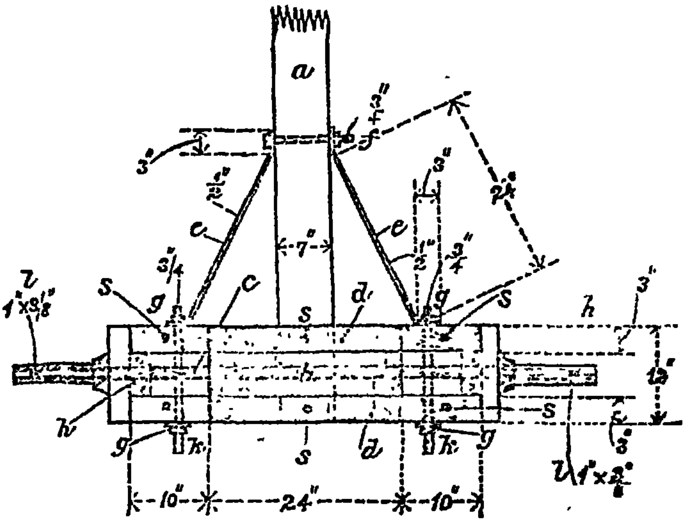


FIG. 21.

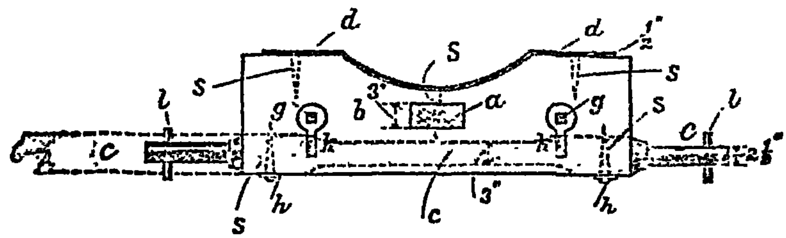
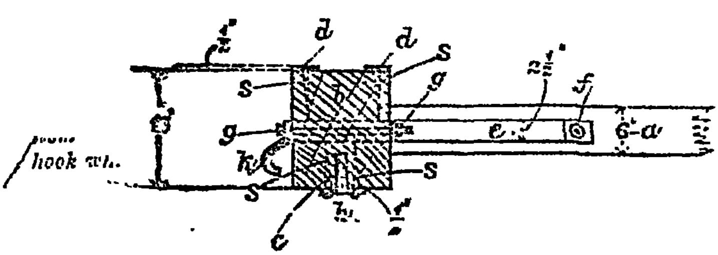


FIG. 22.



Figures 20, 21 and 22 show the construction of the small timber-cart (gindeik) used in Upper Burma for the extraction of teak logs.

Figure 20 is a sectional plan, figure 21 an end elevation, and figure 22 a side elevation. In these figures a *is the shaft;* b *the block of wood which forms the body of the cart;* c *the axle;* d, d *the bands of iron added to prevent the block being worn away by the teak logs carried;* e, e *the iron straps which strengthen the connection between the body of the cart and the shaft;* f *the bolt which fastens these straps to the shaft;* g, g *the bolts which fasten them to the body of the cart and also take the hooks,* k, k *the hooks to which the chains keeping the log in position are fastened;* h, h *are the two plates spiked on to the bottom of the block which keep the axle* c *in position;* l, l *are the linch-pins which keep the wheels from slipping off the axle-trees;* s, s, s *are spikes by which the iron bands* d, d *and the iron plates* h, h *are fastened to the body of the cart. The parts dotted are not actually seen, but are added to show the relative position of the different parts of the cart (Scale 2 feet = 1 inch.)*

roads and that it requires only two or three men to load it. The disadvantages are that it is heavier and is complicated with iron work, which is liable to get out of order; that the loading can only be done at fixed places; and that at least two pairs of buffaloes are required for a log which on the lighter cart could easily be dragged by one pair.

The logs are placed on the carts and secured in position in the manner described in § 17, pages 27 to 29.

§ 21. A larger *gindeik* (see fig. 23) has been tried by the Bombay-Burma Trading Corporation for the extraction of large logs. The chief difference between this cart and the *gindeik* is that the wheels are much larger and that the axle

FIG. 23.

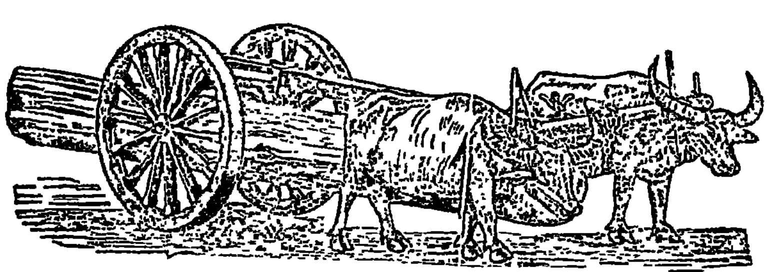


Figure 23 shows a large gindeik with a log in position. The attachment of the yoke to the shaft is that shown in detail in figures 18 and 19, page 32. (Reduced from a photograph taken by Mr. J. W. Oliver, Conservator of Forests.)

bar is bent in the middle so as to allow of the log being slung under it.

This type of cart has been almost entirely abandoned, as it was found that the return journey of the empty carts to the forest depôts takes almost as much out of the cattle as the down journey with a load on. This is due to the great weight of the pole of the cart, which, without a load to balance it, rests altogether on the buffaloes' necks. Furthermore, the large *gindeik*, being of complicated structure, is apt to get out of order, and necessitates the upkeep in the forest of an expensive staff of blacksmiths which is not required if the type of cart described on pages 20 to 27 is used.

SECTION III.—ROLLING ROADS.[1]

§ 22. Rolling roads can be used for the extraction of logs where the slope of the hillside is gentle. They are also constructed round the sides of a hill, immediately below a forest, so that all logs from the forest above may be worked down to them, and then rolled along them to the head of the slide or sledge road along which they are taken to the nearest floating stream which is suitable for drifting purposes. The rolling roads constructed in the Bashahr Forest Division,[2] Punjab, in connection with the extraction of logs from the Upper Sutlej deodar forests, are from 14 to 18 feet wide. The maximum gradient permissible on them is 10° or 1 in $5\frac{1}{2}$. The *best* gradient for a rolling road is 1 in 20 or nearly 2° 50″. As in the case of earth or dry wooden slides, it is not advisable to lay out the road at the same gradient throughout, but the gradient should be changed so that steep sections are succeeded by almost level sections, in order to prevent the logs from becoming uncontrollable. Where steep gradients are unavoidable, they should be short and should be succeeded by level or almost level sections in order to check the velocity of the descending logs. The *mean* gradient of a rolling road should not, if practicable, exceed 3° or 1 in 19. Practically, the Forest

[1] Mr G. G. Minniken, Deputy Conservator of Forests, Punjab.
[2] The "Indian Forester," Vol. XV, page 135, *et seq.*

officer has often to adopt such gradients as the configuration of the ground necessitates, as, for example, when he wants to get his logs across a cliff or a steep rocky slope and has no alternative but to make a rolling road along a certain ledge, or stratum which slopes in the required direction, but with a fall of 1 in 10. Frequently, owing to obstructions in the direction of the alignment of a rolling road, it has to be discontinued and an earth slide or wooden shoot substituted for it, connecting the upper portion of the rolling road to one constructed at a lower level. On steep rolling roads, logs are apt to get out of hand and the workmen are in greater danger of being hurt.

The road is begun[1] by laying a row of large stones at A (fig. 24), and above them rough logs of various kinds, or brushwood, obtained in the clearing the road through the forest. It is found that logs or brushwood are far preferable to stones as they are better able to stand the shocks caused by the rolling timber. A coping C, of rough stone, is added at the outer edge of the roadway, and earth from the cutting above thrown down to give the road a horizontal cross-section.

FIG. 24.

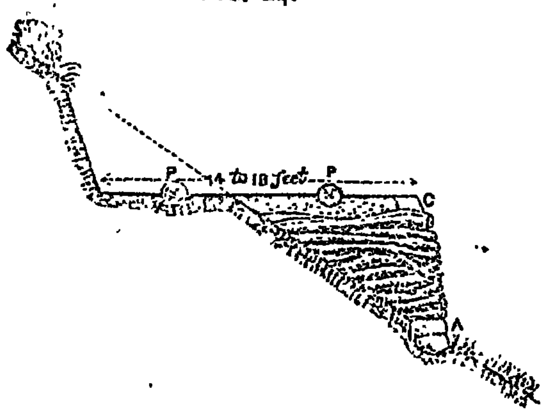


Figure 24 is a cross-section through a rolling road. A is the row of large stones which serves as a footing to the road. C is the stone coping placed along the outer edge of the road; P, P are the poles along which the logs are rolled. (Reduced from an illustration in the "Indian Forester," April 1889.)

[1] Colonel F. R. Bailey, R.E., Conservator of Forests, Punjab (retired.)

On this, poles P, P are laid similarly to rails on a railroad. The poles are well embedded in the earth to prevent their being displaced by the descending logs. Should the route lie across a small ravine or hollow, the latter is either entirely filled up with logs, brushwood, and stones, or it is bridged by a rough structure of logs with poles laid across them so as to form a roadway. The cost of construction of a rolling road is said to be on an average about R10 per hundred running feet.

§ 23. WORKING OF ROLLING ROADS.[1]—The logs to be transported are placed across the road, one behind the other, in batches of from 10 to 20, and are worked down short distances at a time. The coolies commence by wedging the end log of the batch to be moved down the road, with wood and stone. When everything is ready, a few stones are placed on the road about 30 feet in front of the logs to be moved, where they are to be brought to rest again. The wedges which keep the logs in position are taken away, and the logs are, one at a time, gently levered forward and allowed to roll down to the stone stops. If, at starting, the log gets a cant outwards, one end is wedged and the other moved slightly forward until the log will run straight on to the stone stops. Once the leading log of the batch has been stopped, additional stone stops are no longer necessary for those following behind. In this way the logs are gradually moved down until sometimes the entire length of the rolling road is occupied. No ropes are used to move the logs down. Wooden levers, 6 feet long, are the only tools employed.

The workmen stand a few feet in front of the leading log with their levers ready to stop it, if necessary, as soon as the wedges which keep it from rolling have been removed. Occasionally accidents have happened through the stones placed to stop the logs not having been sufficiently heavy for the purpose.

Where the gradients of the slopes of a hillside exceed 25° (or 1 in 2·15 nearly), dry wooden slides not more than 500 feet

[1] Mr. G. G. Minniken, Deputy Conservator of Forests, Punjab.

in length are now constructed in preference to rolling roads, as being a quicker method of transport, and safer as regards the workmen.

Rolling roads are made of various lengths from 300 feet to 2 miles. In their construction sharp curves should be avoided as far as possible, for they considerably increase the labour necessary to keep the logs moving as they should move, namely, at right angles to the line of the road. But in places where it is impossible to avoid a sharp curve, logs can be worked round them as described below.

A pole 5 or 6 feet long is placed obliquely across the rolling road, and the outer pole P (fig. 24, page 37) is taken up. The log is then rolled forward to the point where the curve begins. The inner end of the log is prevented from moving by a wedge driven under it from the lower side, while the outer end of the log is brought on to the pole placed obliquely to the road. The coolies then push the free end of the log, resting on the oblique log as a roller, round through the required angle. This operation is done by degrees, as the log can only be kept properly balanced on the obliquely placed pole for a short time.

The inner end of the moving log rests on a pole which is buried in the ground, until its upper surface is nearly level with the rolling road, in order to facilitate the working of the log round the curve.

When the log has been rotated through the required angle, it is kept from moving by levers until it has been wedged and so kept from moving. If the inner end of the log has come in contact with the bank, it is levered out into its proper position. The outer pole is dispensed with round curves, because the earth of the rolling road offers more resistance to the slipping outwards of the log on the obliquely placed pole on which it pivots than the outer pole P (fig. 24, page 37) would.

The operation of rolling logs along rolling roads with curves on them may seem to be tedious at first, but experience in Bashahr shows that 8 expert workmen can move 20 or 30 large logs round a sharp short curve in one day.

SECTION IV.—SLEDGE ROADS.

§ 24. Sledge roads are roads specially constructed for the transport of timber or firewood from a higher to a lower level in *sledges, i.e.* vehicles furnished with runners—long, narrow pieces of wood placed longitudinally—instead of wheels. The runners of the sledge slide over the sledge road. The sledge road itself is usually specially prepared so as to facilitate the passage of the sledges over it, and also to prevent them from leaving the track on which they run.

The *average gradient* permissible on sledge roads is greater than the maximum gradient allowed on a cart road, but less than the maximum gradient allowed on bridle-paths. The *gradients* of a sledge road vary within comparatively small limits. If the gradient is too flat the loaded sledge will not move down the road in virtue of its own weight; and, on the other hand, if the gradient is too steep, it will move down too fast, the men in charge will not be able to control their rate of progress, and the sledge may leave the road while going round a sharp curve, and may take the sledgemen with it.

§ 25. A SLEDGE (see figs. 35 and 36, page 55; and figs. 41 and 42, page 61) consists essentially of a wooden frame, in which the timber or firewood is placed; and a pair of runners, fastened with screws or bolts, longitudinally and parallel beneath the framework, and sliding over the sledge road.

The front part of the sledge consists of a pair of handles, and if it were desired to build a sledge to travel with either end first there would be a similar pair behind. The handles are let into the runners and strutted into the frame of the sledge. The sledgemen guide the sledge, and control to some extent the velocity with which it moves, by means of these handles.

§ 26. In aligning a sledge road, the choice of alternative routes is much limited by the small variation of gradients permissible and by the necessity for constructing curves of sufficient radius to allow the loaded sledges to pass round them easily. Consequently the gradient of the road cannot be

materially altered in order to avoid difficulties; nor can the road be taken round very sharp curves in order to avoid either the blasting of large masses of rock, or the construction of long bridges and viaducts.

So far, in India, the ground over which sledge roads have been made has been of a very difficult nature, and has necessitated the construction of many more bridges and longer cuttings and embankments than would have been necessary had a bridle-path only been made over the same line of country.

§ 27. In Europe the greater portion of the sledging work is done over snow, the sledges being taken along tracks marked out for this purpose before the snow falls. Where, however, the gradients of the slopes are suitable, the sledges are taken through the forest in any direction. Where the gradient is as low as 4° (7 in 100), horses are used to drag the sledges.

In India, however, it has not been found possible to utilize the snow for sledging purposes as a substitute for prepared tracks, as the snow does not lie in sufficient quantities, or for a sufficient length of time, in any of the forests which have been yet exploited.

The sledge roads in the Jaunsar Forest Division, North-Western Provinces, lie as a rule below the forests which are being worked, at elevations varying from 4,000 to 7,000 feet, where snow rarely falls, and never lies sufficiently long to allow of its being utilized for sledging. The forests from which the trees are cut run up to 8,000 feet, but these slopes are so steep that sledging down or across them is not practicable with the labour available in the locality.

§ 28. GRADIENTS ON SLEDGE ROADS.—The gradient of a sledge road should be such that a loaded sledge will remain at rest on it; but when set in motion, will move slowly down the road in virtue of its own weight.

The gradient given to any individual sledge road will depend upon the dimensions—more particularly the length—of the sledge; the gross weight of the loaded sledge; the width of the cross-pieces, and the kind of wood of which they

are made; and the distance between the cross-pieces themselves.

The gradients of European sledge roads, laid with rough timber, usually vary between 3 in 50 and 1 in 5, that is, between about $3\frac{1}{2}^\circ$ and $11\frac{1}{3}^\circ$; the gradients rarely exceed 15° (27 in 100), even for short distances. Brakes are sometimes used on the steeper gradients to decrease the velocity with which the sledges move.

The gradients on the sledge roads which have been constructed in India vary between 4° and 11°, the best gradient varying between $5\frac{1}{2}^\circ$ and $7\frac{1}{2}^\circ$.

Where the gradient is low, the cross-pieces are placed closer together, so that the sledge rests on a larger number of cross-pieces at one and the same time; and where the gradient is high, the cross-pieces are placed farther apart so that a smaller number of cross-pieces support the sledge at one and the same time. By placing the cross-pieces closer together, a loaded sledge rests on a larger number of supports, and the weight supported by any one of them is less; consequently the friction between the runners of the sledge and the individual cross-pieces (which in this case is the chief resistance to motion, and is a factor of the weight which each cross-piece has to support) is reduced.

The cross-pieces must be so arranged that a sledge never rests on less than two of them at any given moment.

The actual width of the cross-pieces is also of importance. Mr. Hobart-Hampden, Deputy Conservator of Forests, is of opinion that the chief reason why the Thadiár sledge road worked satisfactorily on a lower gradient than the Deota one, is that in the former case the cross-pieces were made of sleepers sawn in two, while in the latter sledge road (the first that was made) whole sleepers were used as cross-pieces.

The smoothness or roughness of the grain of the wood of which the cross-pieces are made is also of some importance.

On the Bamsu sledge road, which was completed and opened for traffic in 1893, and is the latest Indian example, the length of sledges used varies from 9 to $10\frac{1}{2}$ feet. Toon (*Cedrela*

Toona), walnut (*Juglans regia*), deodar (*Cedrus Deodara*), and chir (*Pinus longifolia*) were used for cross-pieces. The gradient of the sledge road varies from 4° to 11°. Where the gradient varies from 4° to 5°, cross-pieces of toon and walnut, which are smooth-grained woods, were used, placed 24 inches apart. Where the gradient varies between 5° and 7°, cross-pieces of toon, deodar, and chir were laid successively in the order named, the distance between the sleepers being increased to 30 inches. On gradients between 7° and 9°, toon and chir sleepers are laid alternately at a distance of 33 inches apart; while, where the gradient is between 9° and 11°, only chir cross-pieces are used, and the distance between them is increased to 36 inches. Chir has a very rough cross grain, but is a soft wood; the grain of deodar is harder, though not so rough as chir, while it is softer and at the same time rougher than that of walnut or toon. When the cross-pieces are placed 2 feet apart, the smaller sledge used rests on three cross-pieces, and where the cross-pieces are 3 feet apart, on two only.

On bridges the gradient should, if possible, be kept fairly low, as it has been found by experience that a loaded sledge moves more rapidly over a sledge road laid on a bridge than it does over a piece of road of the same gradient, laid on a prepared track cut out of the hillside.

The same remark applies to all sharp curves, as the sharper the curve the greater is the tendency for a loaded sledge moving rapidly to leave the track.

Where the gradients approach the maximum allowed, sand is placed on the notches in which the runners move so as to increase the friction; and where considerable lengths of steep gradient occur, the spaces between three consecutive cross-pieces are filled up with earth or sand to the level of the notches so that the runners of the sledge may come in contact with the sand, and the velocity of the sledge may be decreased.

A distance of 30 or 40 feet is left, and then the spaces between three more cross-pieces are again filled up with sand to the level of the notches, and so on.

Where the gradients are very low, a lubricating substance (see § 37, page 57) is placed on the notches before the sledges pass down the road in order to still further decrease the friction.

The experience gained on the working of the Indian sledge roads shows us that the less the gradients differ from the most suitable gradient the better, as the working of the sledge road is easier, and at the same time the wear and tear on the sledges and sledge road is less.

As a general rule, the gradient of sledge roads should not deviate more than 2 or 3 degrees, either more or less, from the most suitable gradient, except for short distances, or over very difficult ground.

§ 29. CURVES ON A SLEDGE ROAD.—The straighter the sledge road is, and the fewer the sharp curves on it, the easier and more satisfactory will be its working. As sledge roads are constructed in the hills, and usually have to be made along the sides of ridges or valleys, it is not possible to make the road absolutely straight, nor is this necessary. Sharp curves, especially on steep gradients, are dangerous even to experienced sledgemen, and may be the cause of serious, if not fatal, accidents to careless or inexperienced hands. If a loaded sledge travelling with a too great velocity comes on to a sharp curve, it cannot follow round the curve, and will leave the road at a tangent, and will go straight on down the hillside, sometimes taking the sledgemen with it.

Curves with radii of 20 and 22 yards were constructed on the Deota sledge road, and after the workmen had become accustomed to the working of the sledges no serious difficulty was experienced in taking the sledges round them. The sharpest curve on the Bamsu sledge road has a radius of 20 yards.

On sharp curves, wooden battens should be nailed along the outside of the notches in the cross-pieces (in which the runners move) on the outer side of the curve, in order to prevent the sledges from leaving the sledge road. This has much the same effect as increasing the depth of the notches themselves; but is preferable, in that the sledge throughout whole length will be in contact with the batten; and any tendency to leave

the road will be effectually checked, and the sledge will be compelled to follow the track round the curve. The outer side of the curve should be laid higher than the inner, in proportion to the sharpness of the curve. A rise of 2 or 3 inches will be sufficient for the sharpest curve admissible on a sledge road. The width of the notches on curves must also be increased so as to allow the runners of the sledge to move easily round the curve and to prevent their jamming in or riding over the notches. The effect of raising the outer side of the curve will be to bring the perpendicular from the centre of gravity of the loaded sledge nearer to the inner notch, and this will help to bring the sledge round the curve.

§ 30. THE GAUGE OF A SLEDGE ROAD.—The gauge of a sledge road, *i.e.* the horizontal distance from the centre of one notch to the centre of the other, cut in the same cross-piece, depends upon the horizontal distance between the runners of the sledge.

The distance between the runners of the sledge used depends, in its turn, upon the weight, bulk and shape of the material to be transported, and also upon the height of the sledge.

The gauge of the three sledge roads which have been constructed in Jaunsar (North-West Himalaya) was determined jointly by the dimensions of the metre-gauge and broad-gauge sleepers which were to be brought down over them. The sledges were made sufficiently wide to hold five metre-gauge sleepers (6¼ feet long by 8¼ inches broad and 4¾ inches thick) placed longitudinally on their smaller sides, or four broad-gauge sleepers (10¼ feet long by 10¼ inches wide and 5¼ inches thick) also placed lengthwise on their smaller sides. The distance between the runners varies in the different sledge roads in Jaunsar from 22 inches to 29 inches, the runners themselves being each 2 inches wide.

In finally determining the gauge of a sledge road, we should bear in mind that the greater the gauge is, the greater will be the width of the sledge road, and consequently the more expensive will it be to construct.

§ 31. LOADS CARRIED BY SLEDGES.—In Europe one man is said to be able to bring down a load of from 1,840 to 2,800 lbs., taking 3 cubic feet of wood stacked as being equal to 82 lbs. (1 maund).

In the German Vosges, the ordinary load of firewood brought down by one man is about 3 steres (105 cubic feet stacked), which, taking 1 cubic foot stacked of fir to weigh 18 lbs. is equivalent to 1,890 lbs.[1]

A working-man in Europe is much more powerful than the ordinary cooly of the North-West Himalayas, or of the jungle tribes of Madras who work in the forests.

The weight brought down on the sledges in Jaunsar, including the weight of the sledges themselves, is, in the case of metre-gauge sleepers, 1,445 lbs.; and, in the case of broad-gauge sleepers, 2,785 lbs. Two men work the sledge down in either case. The sledge used for the transport of broad-gauge sleepers weighs 95 lbs., that used for metre-gauge sleepers 85 lbs. One cubic foot of deodar has here been taken as weighing 40 lbs. The load is 20 metre-gauge or 16 broad-gauge sleepers.

During the construction of the Bamsu sledge road, roughly squared logs were brought down the sledge road on specially constructed sledges (see figs. 38 and 39, page 58). As much as 54 cubic feet solid of chir pine (*Pinus longifolia*) were brought down at one time, and this, taking the weight of freshly cut chir pine to be 38 lbs. per cubic foot, is equivalent to 2,252 lbs. excluding the weight of the sledge. Ten men were employed in working down a sledge load of this description.

§ 32. EUROPEAN SLEDGE ROADS.—Sledge roads in Germany consist of a line of small poles laid along one or both sides of the prepared track, and held in place by pegs. These poles serve as guides for the sledges. Where the sledge road passes across a slope, only one line of poles on the outer side of the track is required, but where the ground is fairly level, two rows of poles are necessary. In either case the runners of the sledge move over the ground, and not, as is the case in India, on a wooden track. Figures 25 and 26 are cross-sections of such a sledge road showing how the poles are laid and kept in position.

[1] Mr. J. H. Porter, Deputy Conservator of Forests, Madras.

FIG. 25.

FIG. 26.

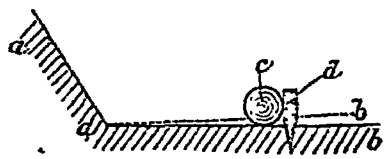


Figure 25 is a cross-section of a sledge road where the ground has no sidelong slope.

Figure 26 is a cross-section of a sledge road on ground which slopes transversely to the direction of the road: the dotted line a, b *is horizontal;* c, c *the poles which form the guides to the sledges;* d, d *the pegs which keep the poles in position. (After Mr. G. R. Forster in "Das forstliche transportwesen.")*

Where the ground is uneven, the sledge road is supported on simple wooden trusses. The height of these trusses is so arranged that the gradient of the sledge road is kept as uniform as possible. The sledge road on such trusses consists of poles laid longitudinally, of sufficient width to carry the sledge, the two outer poles being raised above the inner ones so as to serve as guides and to prevent the sledges from leaving the road. The track on bridges is constructed in a similar manner to that supported on trusses.

The sledge roads in the French Vosges and the Black Forest are frequently prepared with transverse poles, a couple of inches in diameter or less, kept in place by pegs, one at each end, and slightly banked up with earth. The poles are from one to two feet apart according to the gradient or length of the sledge; there are no notches in them. The distance between the pegs is slightly greater than the width of the sledge, and the pegs project an inch or two above the cross-poles and serve as guides to the sledge.—(*Mr. F. A. Lodge.*)

Figures 27 and 28 show the construction of such a sledge road.

FIG. 27.

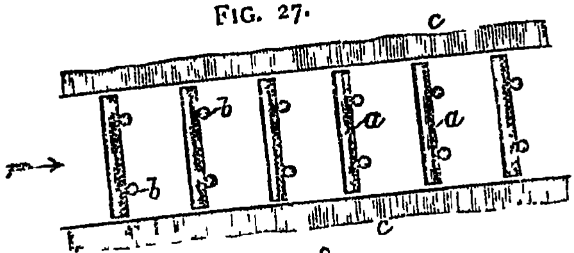


FIG. 28.

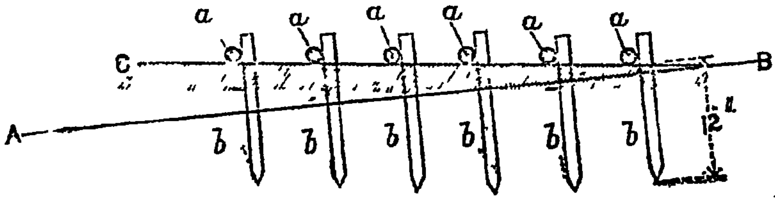


Figure 27 is a plan, and figure 28 a longitudinal section of a sledge road used in the Vosges Mountains; a, a *are the transverse pieces and* b, b *the pegs by which they are kept in position.* A B *is a horizontal line, the slope of the sledge road makes an angle of 6° with* A B.

In the German Vosges the running track (see fig. 40, page 59) consists of pieces of wood 1 metre (39 inches) long laid across the road. These cross-pieces are about one foot apart from centre to centre. They are not pegged down, but simply placed on the ground, the weight of the sledges passing over them pressing them down into the ground. Notches are not cut in the cross-pieces for the sledge runners, and the sledges are kept on them by the man who manages the sledge and walks in front: he holds the handles of the sledge, presses his back against it, and goes at a smart walk but not faster, lest the sledge should become unmanageable. He gets a good hold for his feet against the cross-pieces. No brakes are used. The best gradient is from 4 to 4½ degrees and must not exceed 7½ degrees. The runners of the sledges are well greased.[1]

§ 33. INDIAN SLEDGE ROADS.—The sledge roads which have been constructed in India are of a much stronger and

[1] Mr. H. J. Porter, Deputy Conservator of Forests Madras.

more permanent nature than the European types mentioned above. The sledge road is made of sawn timber (see figs. 29, 30, and 31, pages 50 and 51) laid on a previously prepared track. Two longitudinal lines of scantlings are first laid on the prepared track; cross-pieces are notched on to, and fastened by trenails to, the longitudinal pieces, at fixed distances apart. Two *shallow* notches are cut in each cross-piece to serve as guides in which the runners of the sledge move.

In India, sledge roads have at present only been made in districts where the rainfall is heavy, and where the ground, in consequence, becomes so saturated with water, that no peg placed in it would afford sufficient support to the poles simply laid either longitudinally or transversely on the ground, as is done in Europe. The pegs would all work loose and the sledge road could not be used. The French Vosges system was tried at Deota in 1883, but abandoned, as the cross-pieces rapidly became displaced by the jolting of the sledges passing down the road. The mean annual rainfall at Deota (for 13 years 1883—1895) is 52·47 inches, of which 33·81 inches fall on an average in the months of July, August and September.

§ 34. CONSTRUCTION OF SLEDGE ROADS IN INDIA.—The following description of the construction (see figs. 29, 30, and 31, pages 50 and 51) of the Bamsu sledge road (Jaunsar Forest Division, North-Western Provinces) may be taken as the type of sledge roads as at present constructed in India. Two lines of sawn scantlings (*a*, figs. 30 and 31), 5 inches wide and 5

FIG. 29.

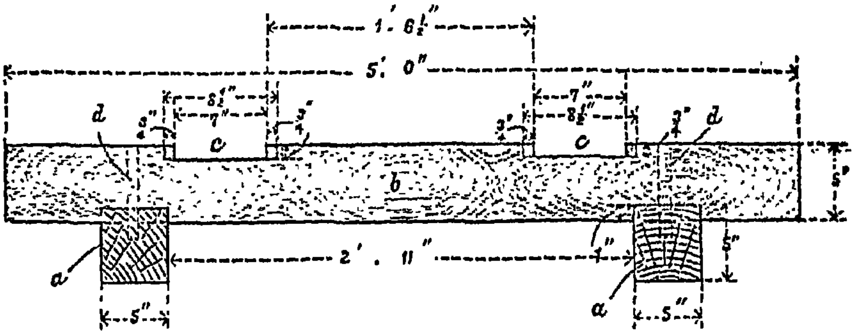


FIG. 30.

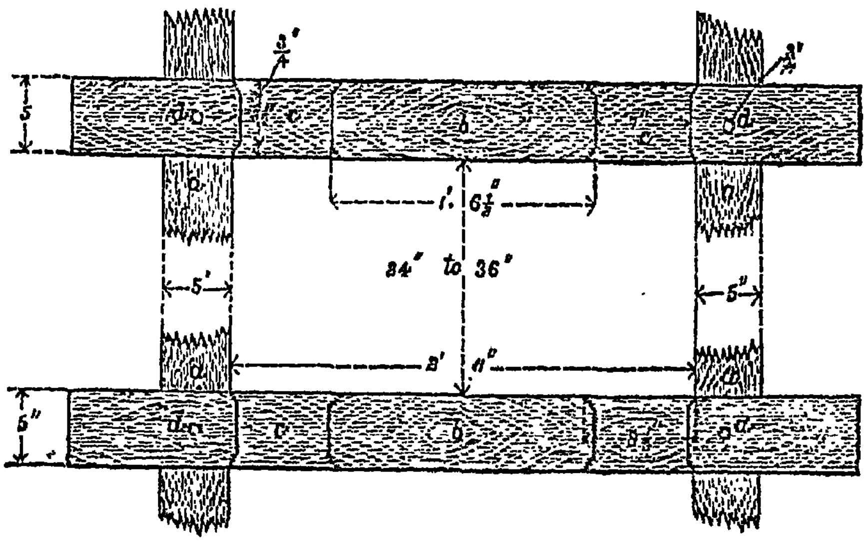


Figure 29 is a cross-section of the Bamsu sledge road; a, a *are the longitudinal scantlings to which the cross-pieces* b, b *are fixed by two trenails* d, d. *The longitudinal scantlings are notched to receive the cross-pieces;* c, c *are the notches cut in the cross-pieces in which the sledges run. (Scale 1 foot = 1 inch.)*

Figure 30 is a plan of the Bamsu sledge road. The same letters are used as in figure 29. (Scale 1 foot = 1 inch.)

FIG. 31.

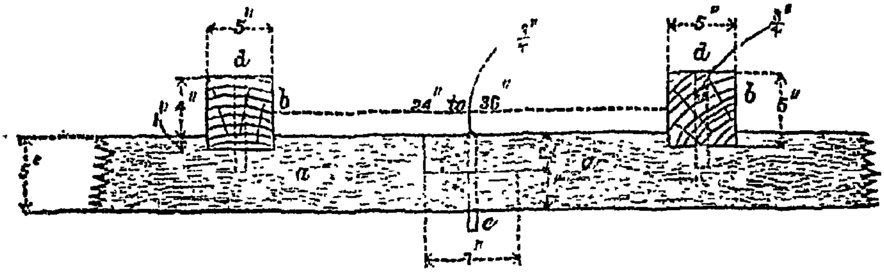


Figure 31 is a side elevation of the Bamsu sledge road, showing the trenailed half-lap joint of the longitudinal; letters as in figures 29 and 30. (Scale 1 foot = 1 inch.)

inches deep, are first laid lengthwise on the prepared track. These scantlings are about 12 feet long and are halved on to each other, the joint being further strengthened by the addition of a stout oak trenail (*d*, fig. 31, above). The distance between the lines of scantlings is on an average 2 feet 11 inches. Notches one inch deep are cut in the longitudinal scantlings to receive the cross-pieces.

The cross-pieces (*b*, *b*, figs. 29, 30, and 31) are 5 feet long, 5 inches deep, and 5 inches wide; they are placed in the notches cut in the longitudinal beams to receive them, and are fastened to the latter by oak trenails (*d*, figs. 29, 30, and 31), three-fourths of an inch in diameter. The distance between the cross-pieces varies as we have seen (see § 28, page 41, *et seq.*) with the gradient.

Notches (*c*, figs. 29 and 30) are cut in the cross-pieces to serve as guides for the sledges. These notches have the corners roughly rounded as shown in figure 30, so as to facilitate the passage of the sledges, especially on curves.

The average width of the notches is 7 inches, and their depth three-fourths of an inch. The horizontal distance between the nearest portions of the notches is 18½ inches, that between the runners of the sledge being 22 inches. The notches are made much wider on curves where the sledges require more play.

The space between the longitudinal scantlings is filled in with the best ballast available, broken stone or sand being preferred if procurable. The sledge road itself is thus made very much firmer and less liable to be displaced by the passage of sledges over it, as the loaded sledges are constantly bumping up against one or other of the sides of the notches, and in so doing necessarily shake the whole structure.

The portion of the prepared track upon which the sledge road is laid is raised, and good drains are made on the inner side of the road so as to keep the track as dry as possible. The water which accumulates in the inner drain is carried off at intervals, under the sledge road, in drains lined with wood so as to prevent the water from percolating into the ballast.

When the difference in vertical height between the upper and lower ends of a sledge road is too great to allow of the sledge road being made in a direct line between the required points, zigzags must be resorted to, and reversing stations constructed at the various zigzags.

If the sledge is made with the runners turned up at both ends, and is provided with handles at either end so that it is immaterial which end moves down first, then a simple zigzag

FIG. 32.

ELEVATION

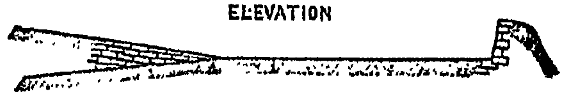


FIG. 33.

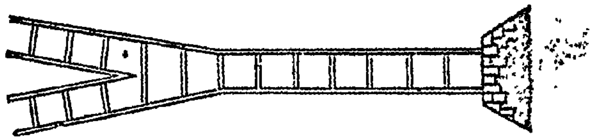


Figure 32 is a sketch elevation and figure 33 a plan of a reversing station on a sledge road for sledges which can move down with either end foremost.

with a short siding to take the sledges, as is shown in figures 32 and 33, page 52, will be sufficient. The siding should be long enough to take two or three sledges at one and the same time.

The addition of a second pair of handles will add to the weight of the sledge, and will also necessitate the runners being made longer in order to receive them. This is a distinct disadvantage in India, because the empty sledges have to be carried up the sledge road by the men (usually two) who work them down, and the weight of the sledge must be limited to that which the men can carry easily.

When sledges, which can only move down in one direction are used, reversing stations, as shown in figure 34, are necessary.

FIG. 34.

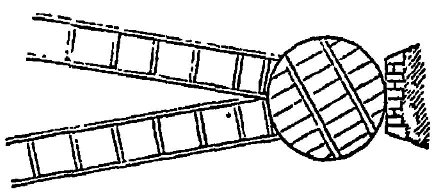


Figure 34 is the plan of a suggested reversing station showing a turn-table for use with sledges which can only move downwards in one direction.

An ordinary cart wheel placed horizontally, and capable of revolving on a vertical axis, makes a good and simple turn-table (see fig. 34) for a sledge road. The wheel must be of sufficient diameter to take the sledge. When the turn-table is placed so that the sledge road on it is in one and the same line with the upper portion of the sledge road, a sledge can be run on to the turn-table. When the sledge is on the turn-table, the latter is turned round until the track is in continuation with the lower portion of the sledge road, and then the sledge is pushed on to it and continues its downward journey.

§ 35. SLEDGES.—The best form of sledge for the transport of sleepers is shown in figures 35 and 36, page 55. This is the

sledge which has been finally adopted on the Bamsu sledge road. The sledges used for broad-gauge sleepers and metre-gauge sleepers vary in length, but are constructed on the same principles. The one shown in figures 35 and 36 is a sledge for metre-gauge sleepers.

The sledge used to carry broad-gauge sleepers is 10 feet 8 inches long and 4 feet 5 inches high, and holds 16 sleepers, while the one figured is 9 feet long, including the runners, 3 feet 5 inches high, and holds 20 metre-gauge sleepers. The materials used in the construction of the sledges are the same in both cases.

The sledge for metre-gauge sleepers consists of two runners made of moru (*Quercus dilatata*), placed 22 inches apart. The runners themselves (*a*, *a*, fig. 36) are 9 feet long, 5 inches deep and 1½ inches wide, the front ends being cut in a curve (see fig. 35). The runners are tied together by two braces (*b*, *b*), 3 inches wide and 2 inches deep. Experience has shown that in working, the runners of the sledge open out in front and the distance between them will often be found to be more than 26 inches; the braces (*b*, *b*) are consequently necessary to prevent the runners from working apart. The framework of the sledge consists of six uprights (*c*, *c*, *c*, fig. 35), three of which are tenoned into each runner, the joints being further strengthened by iron straps (*g*, *g*).

The front pair of uprights are placed about 2 feet from the front end of the runners. Four iron rods (*f*, *f*, *f*, *f*, fig. 37), 1 inch in circumference, are placed between the front pair of uprights and form the end of the sledge. The ends of the sleepers rest against these iron bars when the sledge is loaded.

The uprights are all 3 feet high, 2 inches wide, and 1¾ inches thick.

The second pair of uprights are placed at a distance of 8 inches from the first pair, while the back pair are 5 feet from the second pair. The handles (*h*, fig. 35, page 55) slant forwards and are tenoned and strapped to the runners, about 1 foot from their ends. They are further strengthened by being tied to the front

FIG. 35.

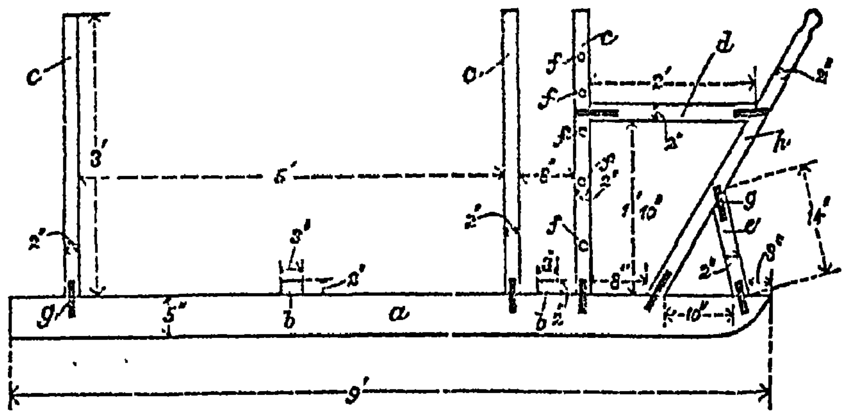


FIG. 36.

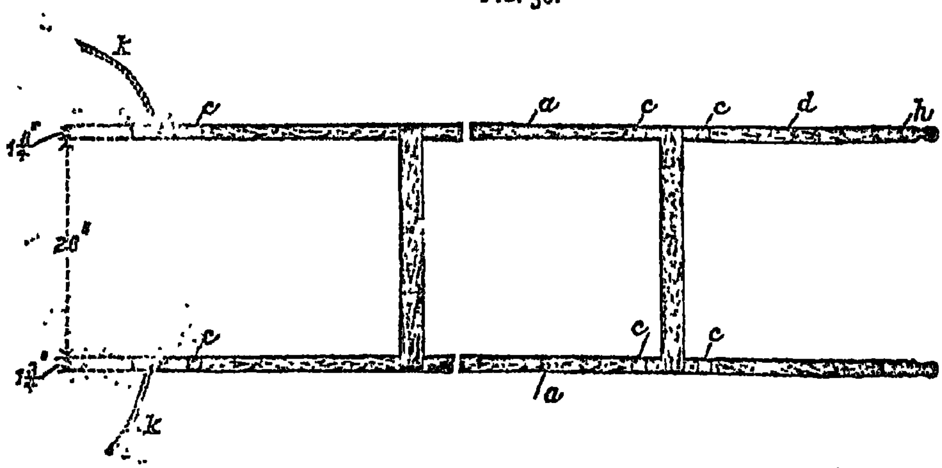


Figure 35 is an elevation of the empty sledge used for the carriage of metre-gauge sleepers. Figure 36 is a plan of the empty sledge; a, a *are the runners;* b, b *battens tying the runners together;* c, c, c *the uprights;* d, d *struts tying the handles* (h) *to the uprights;* e, e *struts tying the handles to the runners;* f, f *iron rods forming the end of the sledge;* g, g *iron straps;* k, k *are ropes attached to ring-bolts fixed into the runners.* (*Scale* = $\frac{1}{24}$.)

pair of uprights (*d*), and strutted to the runners (*e*). The handles are about 3½ feet long and 2 inches by 1¾ inches in section. A loop of rope is fastened to the other end of each runner. The sledge is worked down the sledge road handles foremost. The cost of a sledge is R10.

§ 36. LOADING THE SLEDGE.—Figure 37 shows an end elevation of a loaded sledge. The lower ends of the sleepers rest

FIG. 37.

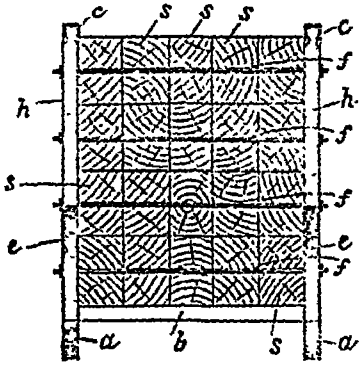


Figure 37 is the front elevation of a sledge loaded with metre-gauge deodar sleepers; a, a *are the runners;* b *the batten (only one is seen) tying the runners together;* h, h *are the handles;* e, e *the struts which tie them to the runners;* c, c *the portion of the uprights seen behind the handles;* f, f *the iron rods which form the front of the sledge, and which pass through the first pair of uprights;* s, s *are the sleepers. (Scale 2 feet = 1 inch.)*

against the rods which form the end of the sledge. The other two pairs of uprights prevent the sleepers from being jolted out. Twenty metre-gauge sleepers, 6½ feet long by 8½ inches by 4¾ inches, or 16 broad-gauge sleepers, 10½ feet long by 10½ inches by 5½ inches, are taken down at one time. The sleepers are arranged in four rows (vertically) of five sleepers each, in the case of metre-gauge sleepers; and four rows horizontally as well as vertically in the case of broad-gauge sleepers. When the sledge is loaded, the upper ends of the uprights are tied together with cord, so as to prevent the uprights from spreading outwards from the pressure of the sleepers; the uprights are only

tenoned into the runners and are not fastened to any other part of the sledge.

§ 37. WORKING OF THE SLEDGES.—The laden sledge is worked down by two men: one man in front guides it by means of the handles, while the other walks behind the sledge and holds the rope. On low gradients the front man pulls the sledge and the man behind pushes it; while on steep gradients the man in front leans backwards, while the one behind pulls the rope at the same time.

On low gradients a mixture of country soap and mustard oil, in the proportion of half a seer of oil to three seers of soap, is applied to the notches to make them more slippery, while on very steep gradients the notches are sanded from time to time to increase the friction and so decrease the velocity with which the sledges travel.

The empty sledges are carried up to the head of the sledge road by the two men who work them down. On the Thadiār sledge road it is found that two men can make five or six trips in a day. The length of the road is 7,960 feet.

The sledge road can only be used when dry; if sledges are taken down when the roadway is wet, they are difficult to start and also difficult to stop.

The sledge road can be used for sledging two or three hours after heavy rain, as the prepared track dries very quickly. The sledge road can consequently be used all the year round.

§ 38. TIMBER SLEDGES.—During the construction of the Bamsu sledge road the large beams which were required for the bridges on the middle section of the road were brought down on sledges which differ in construction from those used for the transport of sleepers.

These sledges were made entirely of moru (*Quercus dilatata*) and consisted of two runners, 10 feet long, 6 inches deep and 2½ inches wide, cut away slightly at one end, and tied together by three cross-pieces, 2½ feet long, 2½ inches wide, and 2½ inches deep. These cross-pieces were nailed on to the runners, one being placed in the middle of their length, and the others at a distance of 9 inches from either end.

FIG. 38

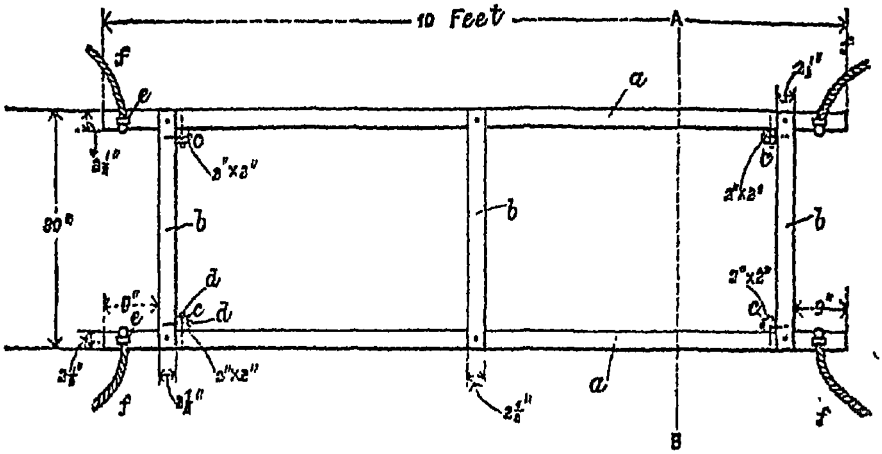


FIG. 39.

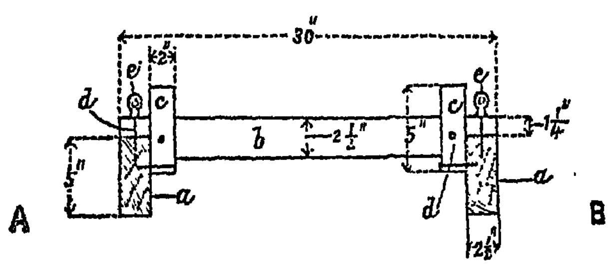


Figure 38 is the plan of a timber sledge used at Bamsu ; a, a *are the runners ;* b, b, b *are the cross-pieces which prevent the runners from spreading out and also form the bottom of the sledge, on which the logs to be transported rest ;* c, c, c, c *are four short posts which keep the logs from rolling sideways off the sledge. These are fastened to both the runners and cross-pieces by nails* d, d, d : e, e *are iron eyes screwed into the runner to which the ropes* f, f, *by which the sledge is worked down, are attached. (Scale 2 feet = 1 inch.)*

Figure 39 is a cross-section of a timber sledge used on the Bamsu sledge road ; a, a *are the runners in cross-section ;* b, *one of the cross-pieces in elevation ;* c, c *the small uprights which keep the roughly-squared logs from rolling off the sledge ;* d, d *the nails by which the uprights are fastened to the runners and cross-pieces ;* e, e *are the eye-holes, through which the ropes by which the sledge is worked are passed. (Scale 1 foot = 1 inch.)*

Four short uprights of morn oak (*c, c*), 5½ inches long and 2 inches square, were placed in the corners made by the junction of the runners and the cross-pieces. These uprights were nailed both to the runners and cross-pieces. They projected 2 inches above the cross-pieces and prevented the roughly-squared logs from rolling about. The logs were tied by ropes to the cross-pieces. The loaded sledge was worked down by men, ropes being attached to staples driven into the runners about 6 inches from either end. The number of men required to work down the

FIG. 40.

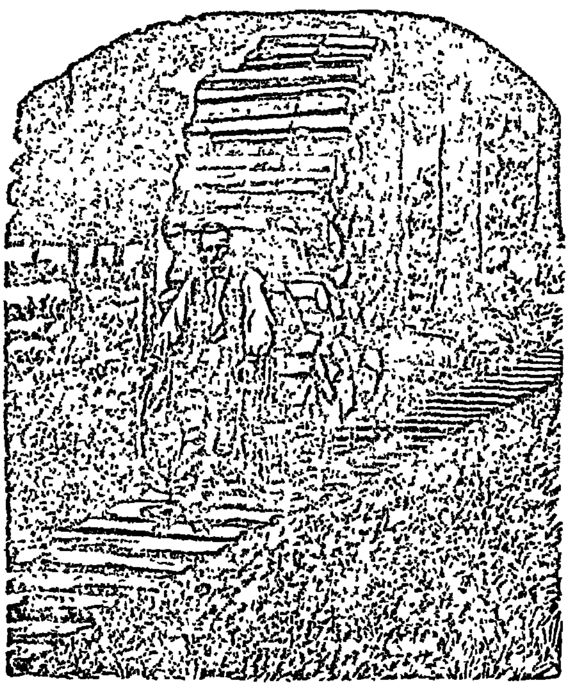


Figure 40 shows the ordinary Vosges fuel sledge loaded. The billets are placed generally transversely, but some are placed longitudinally to prevent them from slipping or rolling when the sledge is in motion. The billets are further secured by a piece of cord attached to the uprights of the sledges. (From a photograph.)

sledge depends upon the size and weight of the log or logs which are taken down. As a rule, six men pulled the sledge down and two held on to the back ropes in order to moderate its speed when necessary.

§ 39. FIREWOOD SLEDGES.[1]—Sledges for the transport of fuel have not yet been used in India, but are extensively used in Europe. Figure 40, taken from a photograph, shows the loaded fuel sledge now used in the German Vosges mountains at Hohwald, while figures 41 and 42 are drawings showing the construction of the same sledge and the dimensions of its constituent parts. These sledges are used singly for logs 4 metres (13·12 feet) long, or in pairs for the transport of longer ones. It will be noticed that the front end of the sledge is higher than the back end. This construction brings the centre of gravity of the loaded sledge further back, and consequently decreases the pressure of the sledge on the sledgeman in front. A loaded fuel sledge is worked down by one man who walks in front of the sledge, and guides it by means of the handles, while he presses his back against the load as he moves down the sledge road. He moves at a smart walk, not faster. No brake is used with these sledges. One man can take down about 3 steres of wood stacked (105 cubic feet), the load being piled up to a height of 10½ feet. The runners of the sledges are greased and the sledgeman has no difficulty in starting the sledge. The billets are placed chiefly across the sledge, but some are put longitudinally (see fig. 40, page 59) to prevent the billets from slipping or rolling out. Ropes are used for tying the fuel to the sledge.

§ 40. WEAR AND TEAR ON SLEDGES AND ROAD.—The runners of the sledges used for the transport of sleepers in Jaunsar last about a fortnight and are by that time worn down to a thickness of 2 inches; soles of moru (*Quercus dilatata*), 3 inches thick, are then screwed on to the runners, the screws being sunk to prevent their tearing up the notches of the cross-pieces. A sole lasts about a week. The framework of the sledge, subject to

[1] Mr. H. J. Porter, Deputy Conservator of Forests, Madras.

FIG. 41.

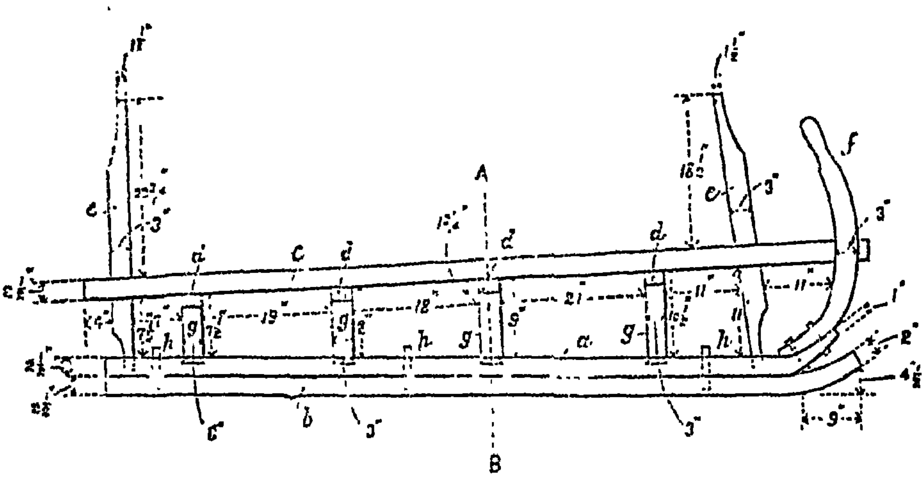


FIG. 42.

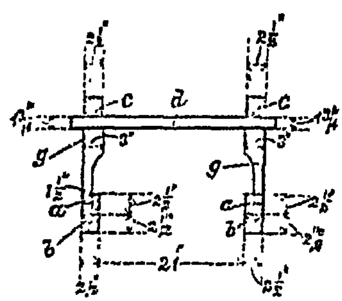


Figure 41 shows in elevation the fuel sledge in use in the Vosges mountains (France) ; a *is the runner of the sledge to which a sole,* b, *is fastened by three wooden pegs* p, p, p ; c *is the other longitudinal piece of wood which forms with the cross-pieces,* d, d, d, d, *the framework on which the fuel is stacked ;* e, e *are the uprights which form the ends of the sledge ;* f *is one of the handles by which the sledgeman guides the sledge. This handle is bolted on to the front of the runner as shown in figure 41 ;* g, g, g, g *are the upright supports to which the cross-pieces are fastened. They are dovetailed into the runners of the sledge and are made purposely of different heights so as to bring the platform on which the fuel rests horizontal.*

Figure 42 is a cross-section of the above sledge along the line A B. *The letters are the same as in figure 41.*

petty repairs from time to time, will last for a whole sledging season, about a year. The wear and tear on the roadway itself is inconsiderable, and the cross-pieces, except where the gradient is steep, rarely need to be renewed during the three or four years during which the sledge road is used.

An examination of the Thadiâr and Deota sledge roads (Jaunsar Forest Division) shows that the notches in the cross-pieces on the steeper gradients are from one-eighth to one-fourth of an inch deeper than they were when the cross-pieces were first laid down. The Deota sledge road was in use from August 1884 to April 1890, and the Thadiâr sledge road was in use from April 1890 up to the end of December 1893. The Deota sledge road is at an elevation of from 7,555 to 6,720 feet and the Thadiâr sledge road at an elevation of about 4,200 feet. The wood used on the latter sledge road, owing to its lower elevation, decayed the more quickly of the two.

§ 41. THE COST OF TRANSPORT BY SLEDGE ROADS, COMPARED TO CARRIAGE BY MEN.—On the Deota sledge road the cost of carriage of a broad-gauge sleeper by manual labour was one anna per sleeper as compared with 3 pies by the sledge road. The cost of transport of sleepers and scantlings down the Thadiâr sledge road compared with that which would have been incurred if men had been employed to carry the produce, is shown in the following table:—

No. of scantlings actually carried.	Nature of the produce.	Cost of carriage by sledge road, each.	Cost of carriage by men, each.
		Pies.	Pies.
337,060	Metre-gauge sleepers . . .	2·66	18
43,410	Broad-gauge sleepers . . .	4·80	36
6,089	Deodar karris (*scantlings*), 6 feet long .	1·67	9
3,624	Deodar karris, 12 feet long . .	2·41	18
2,323	Chir karris, 11 feet long . . .	3·60	18

The length of the Deota sledge road was 5,877 feet, while that at Thadiâr was 7,960 feet.

§ 42. Sledge roads were constructed at Deota and Thadiâr to facilitate the transport of sleepers and other scantlings

from the different parts of the Deota deodar forests of Tehri-Garhwal to the banks of the river Tons. The sleepers are allowed to float down that river until they reach Dakhpathar on the Jumna. They are there made up into rafts and floated down the Jumna as far as Bogriwala, and thence down the Western Jumna canal to Delhi. As the working of the forests passed to other blocks of the Tehri-Garhwal deodar forests, these sledge roads were abandoned, as it would not pay to break them up and export the wood of which they were made, even as fuel. When the Thadiâr sledge road was given up, it was found that a large proportion of the wood used in construction was too much decayed to be fit for any purpose.

A note on the working of the Deota and Thadiâr sledge roads will be found in Appendix I, page 333, to this Volume.

SECTION V.—FOREST TRAMWAYS.

§ 43. Forest tramways may be defined as light railways of a small gauge, where the motive power is usually either the ordinary draught animal of the country or man. In India steam engines have as yet rarely been used on forest tramways.

Trucks, with flanged wheels, run on a road formed of two longitudinal rails laid down at a fixed distance apart; the rails may be of wood, wood faced with iron straps, iron or steel, and are usually fastened on to or fixed into wooden or iron sleepers.

The resistance to traction on a well-made tramway is much less than on a roadway under similar conditions. On a tramway the resistance may range between 7 and 15 lbs. per ton and upwards, according to the condition of the track. On a good road surface the resistance to traction will vary from 46 to 200 lbs. per ton, according to its state of smoothness and hardness. An average resistance for a well-kept road is over 65 lbs. The tractive power applied to a vehicle on a tramway will haul many times the load that it could drag along an ordinary road surface.

Tramways are usually constructed over level or fairly level ground. The maximum gradient which can be economically adopted depends upon the tractive power for ascents, and on the

brake or retarding power for descents. The resistance to traction increases with the ratio of the sine of the angle of ascent to the horizontal, so that

$$R = r\ P \text{ sine } A$$

where R=the total resistance,

r=resistance per ton of load and vehicle on the level,

A=the angle of ascent,

P=the total weight of load and vehicle.

Where tramways are taken up or down considerable inclines, an efficient system of brakes must be introduced, and this will add considerably to the initial cost as well as to the wear and tear of the line and rolling stock. The system of brakes must, as far as Indian forest tramways are concerned, be very simple in construction, strong, and not liable to get out of order, as only unskilled labour is available.

So long as the line of the tramway is practically level, and the gradient, either up or down, not more than 2 in 100 (0°43′) when loads of 1 ton per truck are carried over the line, or 3 in 100 (1°9′) when lighter loads are transported, no brakes will be necessary; but as soon as the down gradient exceeds this amount—and it is almost impossible, except in the plains of India not to exceed this gradient—brakes become necessary and will add considerably to the difficulty of working the line with the nature of the haulage and labour available in this country. Consequently, whenever practicable, it will be found advisable to keep the gradient of a tramway less than this ratio.

§ 44. Where forest produce has to be taken from a higher to a lower level, tramways, besides being more costly, are not nearly so effective as sledge roads. In the plains, they may be advantageously constructed where the produce of a forest must pass along one definite line of export and where the traffic is sufficiently large and constant to warrant the initial outlay. Where carts or other means of transport cannot be obtained in sufficient numbers when required, the construction of a tramway will often render the executive quite independent of local transport.

The more completely a tramway is utilized, the greater will be its financial success, because economy is effected by the *direct saving in the cost of the transport of the material taken over the tramway;* and if the rolling stock is not fully utilized throughout the whole of the working season, the saving must necessarily be less than it *might have been* if the whole of the rolling stock had been fully utilized throughout that period.

Two conditions are necessary before a forest tramway can be profitably laid down. On the one hand, there must be a constant and sufficient demand for the produce to be transported and, on the other hand, there must be a sufficiently large quantity of that produce near the line of the tramway or its branches available for transport. Where the whole of the produce of a compact block of forest can be taken along one line, in order to reach the market, it may be advantageous to construct a tramway. Again, where a plantation is being worked for fuel under the coppice sylvicultural system, a tramway along the common line of export, with temporary branch lines to the various annual coupes, may prove to be the most economical mode of extracting the produce.

The whole question of whether a forest tramway can be introduced with advantage depends upon the amount of the direct saving in transport, and this in its turn depends upon the volume of the produce to be exported. This question has already been discussed in § 4, page 4, *et seq.*

Forest tramways will undoubtedly come into much more general use as the demand for forest produce increases, and as more distant forest areas, which have not yet been worked, have to be opened up in order to meet the demands of the market. Cart roads, or other means of export, must be constructed in order to allow of the extraction of the forest produce, and when the question of how to open up a given forest has to be settled, it will often be found cheaper to lay down portable forest tramways than to make cart roads, which are necessarily much wider and cost much more to make in a hilly country.

In the case of the Sihlwald[1] forest, near Zurich in Switzerland, it has been found cheaper to lay down portable tramways than to construct cart roads. This forest is in the Sihl valley, and is situated on steep hill sides much intersected by ravines. It has been found that (1) not only is the original cost of the construction of the track and purchase of the tramway and rolling stock less than the cost of making a cart road (which is necessarily much wider), but that (2) the cost of up-keep of the tramway is less than that of a cart road, and (3) that a greater quantity of material can be transported along the tramway in a given time, while (4) the tramway occupies less space, and consequently the actual productive area of the forest is greater than would have been the case had cart roads been made.

It should, however, be mentioned that the configuration of the Sihlwald is such that it has been found practicable to construct the tramways with a constant down gradient, and that there is not a single up gradient on the line. The conditions are consequently most favourable for the introduction of a tramway, as the cost of working the fuel and timber over the line is reduced to a minimum.

§ 45. Forest tramways may be divided into—

1. Permanent tramways.
2. Portable tramways.

Permanent tramways are those which are laid down and are not taken up, until the whole of the forest produce has been removed. The rails are generally long, heavy, and not easily moved. The actual weight of the rails and the sleepers to which the rails are fastened is not of primary importance. Wooden sleepers are generally used.

Portable tramways, as their name implies, are tramways which are so constructed that they can be easily carried from one place to another. The rails and sleepers are usually made in sections sufficiently light to allow of their being carried from one place to another by two or three men. The ends of the sections are constructed in such a way that they can be

[1] Journal of a tour made in the Continental Forests of Europe (1893), by Mr. J. Copeland, Deputy Conservator of Forests.

quickly and firmly joined to each other. The solidity and firmness of the tramway are of great importance, in order to ensure smooth working under heavy loads. The weight of the rails and sleepers must be adapted to the means available for moving the sections from place to place; if too light, the tramway cannot be kept in good order, and the trucks will be easily derailed.

The rails and sleepers in portable tramways are either permanently fastened together as in the "Décauville" pattern, or are made so that they can be easily taken to pieces and put together again as in "Fowler's" portable railways. In both patterns, sections of the line can be carried from one place to another and laid down as may be required by two or three men. If the rails are made separate from the sleepers, the line occupies much less space in transport, but, on the other hand, the fact of having the rails firmly fastened to the sleepers is said to add considerably to the rigidity of the line itself.

Portable tramways are now largely manufactured in Europe for the transport of agricultural and forest produce, and are used in many parts of the world where a difficulty is experienced in obtaining either manual labour or draught animals in sufficient numbers. In India *permanent tramways* have been used to a small extent in connection with the extraction of sleepers in the North-West Himalaya and elsewhere: while *portable tramways* have been constructed in the Madras Presidency for the extraction of timber and firewood; at Changa Manga in the Punjab, for the extraction of fuel from the coppice wood at that place; and in the Andaman Islands for the carriage of padouk squares and firewood.

In the Punjab, the "Décauville" pattern was used; but in the Madras Presidency and the Andamans, "Fowler's" portable railway has been exclusively adopted.

The construction of permanent tramways presents no peculiarities, and need not be described in detail here, so that the two types of portable tramways only remain to be considered. The illustrations are taken from the catalogues of the companies who manufacture the tramways and rolling stock

described, and the blocks have been supplied free of cost by the managers of the respective companies.

Of course, there are many other makers of portable tramways, among whom are Messrs. Dick, Kerr & Co., Kilmarnock; Messrs. Howard & Co., Bedford; Messrs. Bagnall & Co., Stafford; Messrs. Kerr Stuart & Co., Stoke-upon-Trent; Messrs. Harmann & Son, Osnabruck, Hanover, etc., etc.

§ 46. PORTABLE TRAMWAYS, FOWLER'S PATTERN.—The portable tramways used in India are those for animal power, system A of the catalogue.

Fowler's Light Railways have been used in the Madras Presidency and the Andamans, and were procured from Messrs. John Fowler & Co., Limited (Leeds), and of 89, Clive Street, Calcutta. They are constructed according to Greig's patent. The firm construct several systems of portable lines which fall into two principal types, the differences between the various systems being chiefly differences in the weight of the rails used. Lines of both types have been used in the Indian forests. In the type used in the Madras Presidency the rails are fixed on to sleepers of rolled steel, which have a deep corrugation down their centres (see figs. 43 and 44, page 70) to receive the hook-bolts which fasten the rails to the sleepers.

In the type used in the Andamans the sleepers are of steel, of trough section (see fig. 48, page 73) with tongues (*b*, *b*) punched out of the sleepers to receive the foot of the rail. The outer flange of the rail is pushed under the tongue *b* of the sleeper and kept in position by a feather-edged clip washer-plate *d*, placed over the inner flange of the rail and bolted to the sleeper by a bolt and nut *c*, which passes through the sleeper and the washer.

The following description of the tramways and trucks suited for forest works (in this paragraph) has been chiefly extracted from the descriptive catalogue of that firm.[1]

The portable tramway is constructed on the principles of distributing the load upon a large number of wheels, and of

[1] Descriptive Catalogue of Light Railways and Rolling Stock. (John Fowler & Co., Limited (Leeds), No. 45, Part IV of 1893.)

making the tramway itself, as well as the rolling stock, as light as possible, consistent with strength, so that the sections of the line itself as well as the trucks can be carried from one place to another by two or three men without any mechanical appliances.

The advantages claimed for this system of portable tramway are—

(1) That the gauge is so chosen, in every case, that it combines the maximum of strength with the minimum of weight.

(2) That the different parts of the way are interchangeable, can all be carried by one or two men, and can be removed without any mechanical appliances.

(3) That the fastening of the rails to the sleepers weakens neither the one nor the other.

(4) That the way can be laid down without any skilled labour.

§ 47. In system B of Fowler's portable tramways, the type used in the Madras Presidency, the sleepers are of rolled steel, with a deep corrugation down the centre to receive the hook-bolts (*c*, *c*, figs. 43 and 44, page 70) which keep the rails in position. The rails and sleepers are quite separate from each other. Steel chairs are riveted to the sleepers, and the rails are firmly fastened to the sleepers by means of hook-headed bolts.

Double sleepers are used to connect the rails with each other, one end of each rail is fastened to this double sleeper, and the necessity of any special joint is thus obviated. Where double sleepers are used, eccentric tongs (see fig. 45) are necessary to place the rails in position, the rails are first fixed into one double sleeper and the intermediate sleepers which support them, the free ends of the rails are then too far apart to be placed under the clip-chairs of the other double sleeper. These ends are pressed together by means of the tongs, and slipped under the riveted clip-chairs of the other double sleeper by slackening the tongs.

FIG. 43.

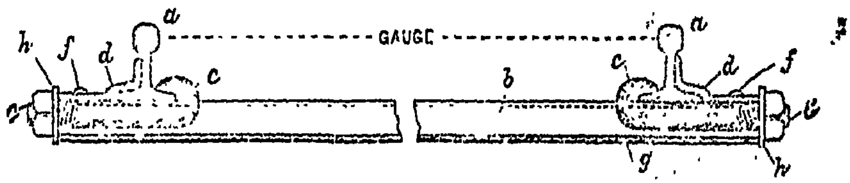


FIG. 44.

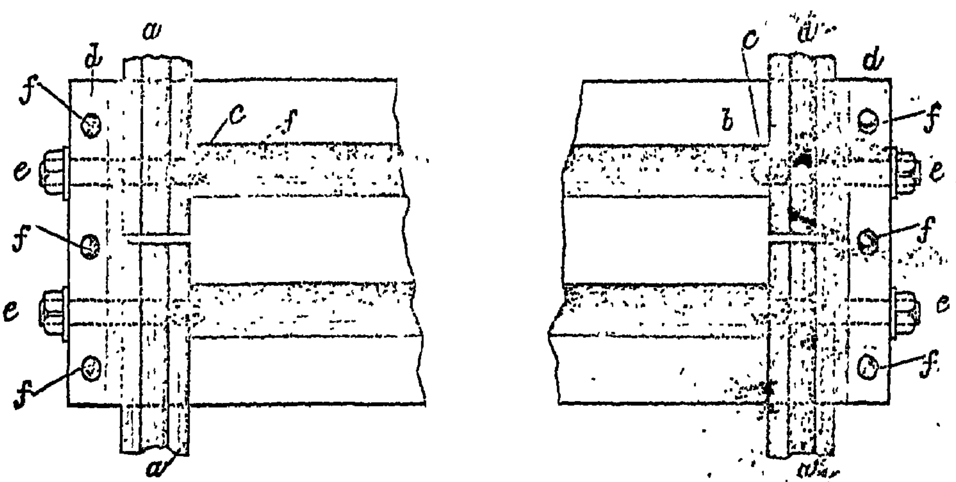


Figure 43 is a cross-section of a sleeper and rails of one of Fowler's portable systems of railway; a, a *are the rails seen in cross-section;* b *is a steel sleeper in longitudinal sectional elevation;* c, c *are the hook-headed bolts which fasten the rails to the sleepers;* d, d *are the chairs which with the hook-bolts fix the rails on to the sleepers;* e, e *are the nuts of the hook-bolts;* h *is a washer between the nut* e *and the edges of the chair and sleeper;* f *is the rivet fastening the clip-chair to the sleeper;* g *is part of the sleeper in cross-section.*

Figure 44 is a plan of a double sleeper showing how it joins together two rails; a, a *are the rails in plan;* b *the double-sleeper;* f *the corrugation made in the sleepers to receive the hook-headed bolts;* c, c *are the hook-headed bolts;* d, d *are the chairs which with the hook-headed bolts fasten the rails to the sleepers;* e, e *are the nuts by means of which the hook-headed bolts are tightened up;* f, f *are rivets fixing the chairs to the sleepers.*

FIG. 45.

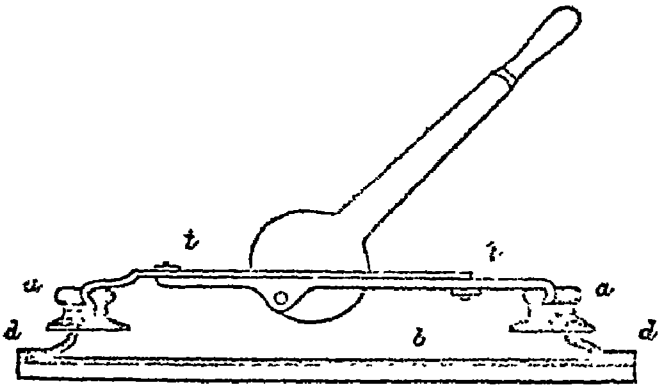


Figure 45 shows the use of eccentric tongs in laying Fowler's portable railway; t, t *are the tongs;* a, a *the rails in cross-section;* b *the sleeper in sectional elevation;* d, d *the chairs which are riveted to the sleepers. The rivets joining the chairs to the sleepers have been left out.*

The tongs open and close by the working of an eccentric disc in their mid length. They consist of two flat bars, superposed so as to slide one on the other. The outer ends of these bars are bent to a hook which clips the rail head. Each bar has a long slot cut near the overlapping plain end and through this slot passes a bolt, with nut and washer, holding the upper and lower bars loosely together, and permitting sliding. To the lower bar, which is deepened and holed, is pivotted an eccentrically fixed disc forming the lower part of the projecting handle. This disc works in slots cut through both bars in such positions that the movement of the handle from left to right or *vice versâ* causes the hook ends to approach or recede from one another.

If double sleepers are not used at the ends of the rails, a joint (see fig. 46) similar to that used in Décauville's portable tramway is necessary. This joint is formed by riveting two fish plates to one end of a rail, and a sole plate to the end of the rail which is to be joined to it. When the ends of the rails

are brought together, the web of one rail slides in between the projecting fish plates of the other, and the sole plate of the latter passes under the flange of the former, thus making the abutting ends of the rails in line and level.

FIG. 46.

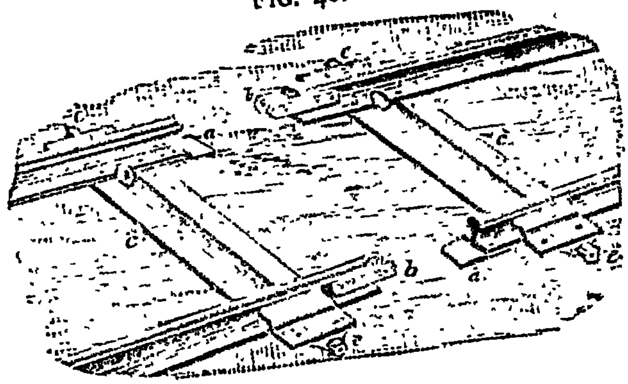


Figure 46 shows how the sections may be joined without using double sleepers; a, a *are the sole plates which pass under the flanges of the rails of the next section;* b, b *are the fish plates projecting and fitting on each side of the web.* c, c *are the corrugated sleepers;* e, e *are the hook-headed bolts.*

This type of portable tramway is made of gauges varying from 16 to 30 inches, and with rails weighing from 10 to 18 lbs. per yard to suit the character of the haulage used, which may be men, draught animals, or steam. It is suitable for light loads where the weight per truck does not exceed one ton. When the loaded trucks weigh more than one ton, the semi-portable lines should be used, or else the type of line shown in figure 48, page 73.

For rails up to 14 lbs. per yard the sleepers are placed 3 feet 9 inches from centre to centre; for heavier rails the distance is reduced to 3 feet.

Semi-portable lines are made of gauges varying between 18 and 30 inches with rails weighing from 18 to 32 lbs. per yard.

FIG. 47

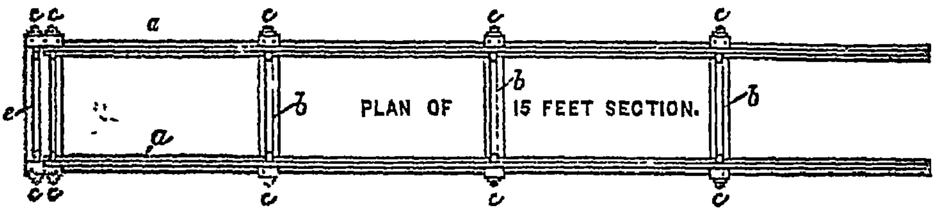


Figure 47 shows in plan a section of a portable railway suitable for manual or animal power; a, a are the rails in plan; b, b the single and e the double sleepers; c, c are the hook-bolts which fasten the rails to the sleepers.

§ 48. In system DD, the type used in the Andamans, the rails (*a*, *a*, fig. 48) fit under clips (*b*, *b*) formed by slitting the top of the sleeper and bending up a portion of it; the rails are kept in position by the addition of a feather-edged clip washer plate (*d*), a bolt and nut (*c*).

FIG. 48.

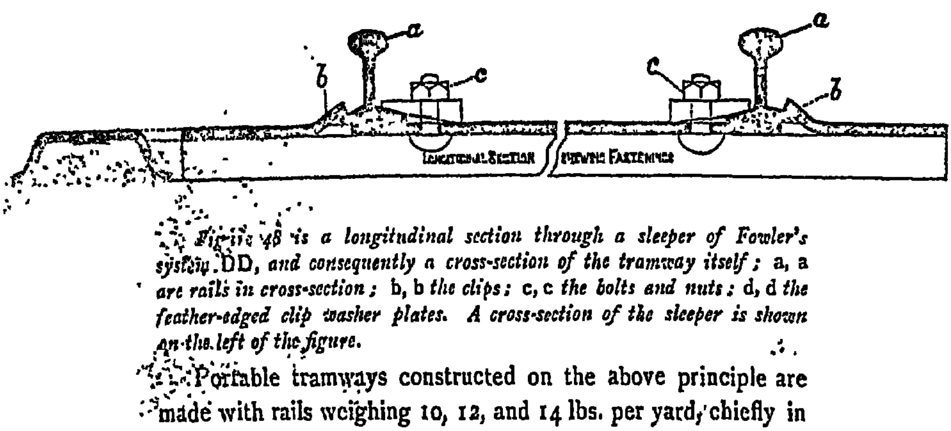


Figure 48 is a longitudinal section through a sleeper of Fowler's system DD, and consequently a cross-section of the tramway itself; a, a are rails in cross-section; b, b the clips; c, c the bolts and nuts; d, d the feather-edged clip washer plates. A cross-section of the sleeper is shown on the left of the figure.

Portable tramways constructed on the above principle are made with rails weighing 10, 12, and 14 lbs. per yard, chiefly in 15 feet lengths, with fish plates and bolts for the joints; for rails of these weights the sleepers are placed 3 feet 9 inches apart from centre to centre. For rails weighing 14, 18, and 22 lbs. per yard (made chiefly in 15 feet lengths), the sleepers are

placed 3 feet apart from centre to centre, and project 6 inches beyond the rails on either side.

The semi-portable lines of this system have rails weighing 18, 21, and 24 lbs. per yard, chiefly in lengths of 21 feet; the sleepers are placed 3 feet apart from centre to centre, and project 7½ inches beyond the gauge line.

§ 49. Curves of radii varying from 18 to 100 feet for the portable tramways are supplied in sections with sleepers complete, but it will be found more satisfactory to buy a rail-bending machine instead of fixed curves.

Moveable, right or left hand crossings, crossings for two, three, or four lines, with switch boxes and hand levers, can be supplied if required. The four-line crossing is really a crossing for two lines at right angles to each other.

Moveable crossings are very useful when a temporary diversion from the main line is required (*e.g.* to take a side line into a compartment being felled at some distance from the main line), as they obviate the necessity of removing part of the main line, and can be placed in position or removed in a few minutes. A moveable crossing consists of a length of rails (15 feet long), of which the ends that fit on to the main line are cut down in a slope, the thin end resting on the main line; the sleepers have grooves cut under them where they lie on the main line; the rails of this main line fit into these grooves and steady the crossing. The sleepers, except the end ones, are made extra long to allow one end being fixed on to the rails and the other end to be packed up to the required height. (*Mr. F. A. Lodge.*)

Portable turntables and weighing machines, either separate or combined, as well as eccentric tongs, which are necessary for laying the tramway when the rails are made separate from the sleepers, are also supplied by the manufacturers, who also supply suitable machines for bending rails to curves of any radius.

§ 50. Wagons and trucks of many kinds, and specially adapted for the different kinds of traffic, are made by Messrs. John Fowler & Co.

Two kinds of trucks have been used for the export of forest produce in Madras: the first kind being suitable for the transport of the fuel, the latter more especially for that of timber in the log. In either case the trucks are made entirely either of iron or steel.

In the truck, fig. 49 (type J of the Catalogue), which has been used for the transport of fuel, the frame in which the axles of the wheels work are of iron or steel (channel section), and are curved together at both ends so as to form central buffers. They are fitted with swivelling draw-gear, steel axles, grease axle-boxes and springs. An iron cradle, open at the sides, is fixed on to this framework to hold the fuel, which is placed in it transversely.

FIG. 49.

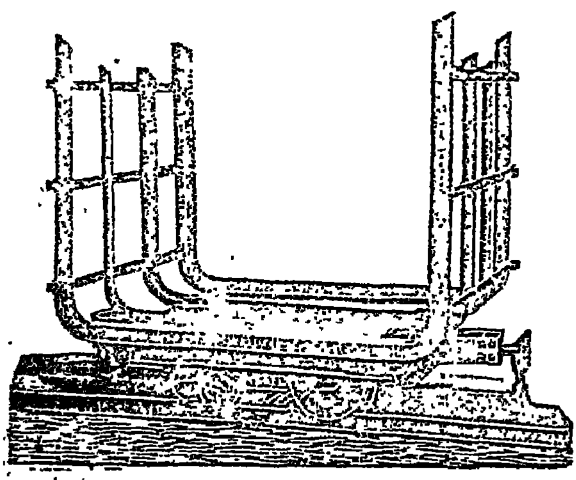


Figure 49 is the type of wagon, sugarcane truck (type J) used for the carriage of fuel on the Madras forest tramways. The axle-boxes are placed outside the wheels. The load of the truck is 20 cwt. (27·32 maunds of 82 lbs. each). The truck is made entirely of iron and steel.

This form of truck is also made with a brake worked by a man standing on a platform attached to one end of the truck. This platform also carries a tool box.

§ 51. The trucks used as timber wagons consist of two bogie trucks coupled with a chain, as shown in figure 50 (type H H of the Catalogue).

FIG. 50.

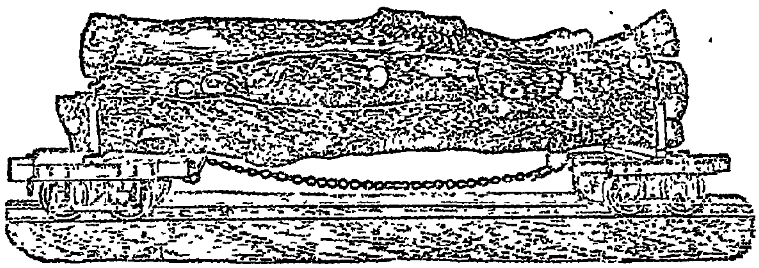


Figure 50 shows the bogie trucks used on the Anamalai forest tramway, Madras, for the transport of logs. The trucks will carry from 3 to 6 tons (82 to 164 maunds of 82 lbs. each). The trucks are furnished with strong springs fitted above the axle-boxes to decrease the wear and tear on the axles, and also swivelling forks which allow of the trucks turning round corners independently of the position of the log.

The frames of these bogie trucks are of channel iron or steel, and are furnished with swivelling draw-gear. The wheels are of iron or steel, and are furnished with steel axles, grease axle-boxes, and springs. Each bogie truck is supported by four wheels, and is fitted with an improved swivelling fork (on which the logs rest), constructed to rotate on its axis independently of the framework of the truck; the forks are provided with chains for securing the load; in consequence of this arrangement, long logs can be taken round curves of a radius of as little as 35 feet.

It will be noticed that both kinds of trucks are furnished with strong steel springs, which are said to be a source of economy, in that they reduce the wear and tear on the rolling stock, ensure smooth and easy running, and are a safeguard against the derailment of trucks on roughly laid lines.

Axle-boxes.—Axle-boxes (see figs. 58, 59 and 60, pages 83 and 84) fixed on to the framework of the trucks are supplied for use of oil or grease for lubrication. The wheels are firmly

fastened to the axles, and cannot be separated from them; they rotate consequently as a whole. The *journal* is the part of the axle on which the frame of the truck rests; it is housed in the axle-box. The axle-boxes may rest on journals formed on the outer, or on the inner, side of the wheels themselves. Where the load on a truck is not more than one ton, outside axle-boxes are recommended; but for loads greater than one ton, inside axle-boxes are more suitable.

The axle-box is fitted with a gun-metal step or bearing, resting on the journal, which can easily be replaced when worn out. The grease boxes are furnished with hinged lids, while a pad placed under the axle keeps the journal constantly clean and well lubricated.

The wheels are either of chilled cast iron or of cast steel, and are bored, slotted, and keyed on to Bessemer steel axles.

The diameter of the axles varies from $1\frac{3}{4}$ to $2\frac{1}{4}$ inches with the load to be carried.

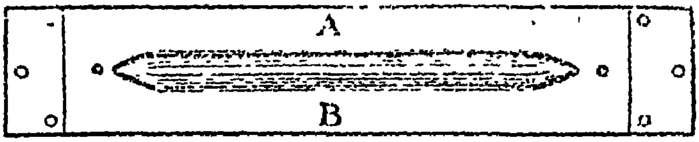
§ 52. DÉCAUVILLE PORTABLE RAILWAYS.[1]—These portable railways are constructed on the same principles as those upon which Fowler's portable railways are made, *viz.* the distribution of the load over a large number of axles, so that the weight which each axle has to support is reduced as far as possible, as are also the dimensions of the rails that can be used to carry a given weight. The motive power may be men, draught animals, or the steam engine, but only such types as are suitable for haulage by men or draught animals fall within the scope of this work.

The railway is made up of sections of varying lengths, the rails being riveted firmly to, and being inseparable from, the sleepers.

Both rails and sleepers are of steel. The sections are made both in straight and curved pieces, or combined so as to form crossings. The joints of successive sections are made (see fig. 53, page 78) as in Fowler's tramway (see fig. 46, page 72).

[1] Catalogue Illustré de Décauville, No. 81, June 1892. 13 Boulevard Malsherbes, Paris.

FIG. 51.



Vue en plan de la traverse emboutie en acier

(Plan of sleeper of embossed steel.)

FIG. 52.

Vue en Coupe.

(Cross section on A B.)

Figure 51 shows a plan of the embossed steel sleeper used on railways of a small gauge. A sleeper thus formed does not sink as readily as a flat one would in moist soil.

Figure 52 is a cross-section of the same sleeper along A B.

FIG. 53.

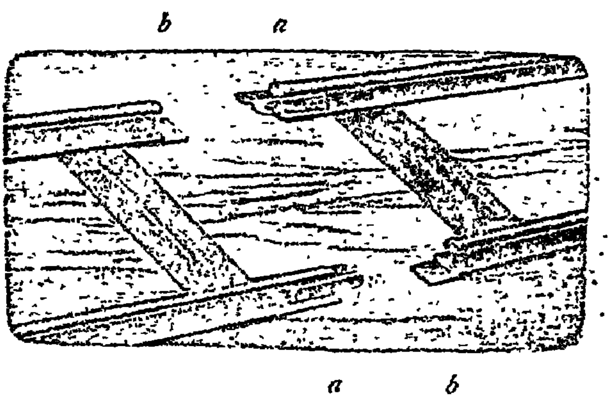


Figure 53 shows the method of uniting two sections; a, a *are the fish plates, and* b, b *the sole plates, by means of which the junction is effected.*

The fish plates have a hole bored in each and a corresponding hole is pierced in the web of the rail, so that the two sections may be securely bolted on to each other if this is considered necessary. The rails are cold riveted on to the sleepers.

The chief difference between Fowler's and the Décauville types of portable railways is that, in the former, the rails and sleepers are separate one from the other; whereas, in the latter, the rails are riveted on to the sleepers, except in some of the heaviest types of rails, when the gauge is considerable; and even then the manufacturers recommend the rails being riveted to the sleepers, wherever the sections thus formed can be carried by the usual means of transport available in the country where the line is to be laid.

The objection to having the rails fixed to the sleepers is that curves of any required radius cannot be formed at will, and that only the set curves supplied by the manufacturers can be used.

The rails are of the ordinary flanged type used on regular railways, only the flat base is made wider proportionately to the size of the head.

The weight of the rails used for the portable tramways varies from 9 lbs. to 14 lbs. per yard (4·5 kilos to 7 kilos[1] per metre) and those used for semi-portable lines from 19 lbs. to 26·6 lbs. per yard (9·5 kilos to 12 kilos per metre).

The gauge for portable railways varies from 18·75 inches to 29·53 inches (0·40 metres to 0·75 metres), and for semi-portable lines, gauges of 35·43 and 39·37 inches (0·90 and 1·00 metres) have been adopted. Rails weighing 30·1 lbs. per yard (15 kilos per metre) are made for railways of gauges of 23·62 inches to 39·37 inches (0·60 to 1·00 metre).

The gauge is measured from the inside of the head of one rail to the inside of the head of the other.

The sleepers are made of steel, and two different types are made. In the first the sleeper does not extend beyond the outer edge of the rail flange, and the central part of the sleeper is embossed (fig. 51, page 78) so as to make it stronger, and to allow of its affording a firmer support to the rails, especially on soft soils, than if its base was quite flat. The second is of steel channel section, laid on its wings as shown in figure 54, so as to

[1] The following equivalents have been used in changing French measures into English ones:—

1 metre = 3·28 feet. 1 kilo = 2·20 lbs. 1 metre = 39·37 inches.

give the sleeper a firmer grip of the ground or ballast in which it is laid. The ends of the channels may be blocked to obtain greater resistance to lateral pressure. The section type of sleeper is much the stronger of the two.

FIG. 54.

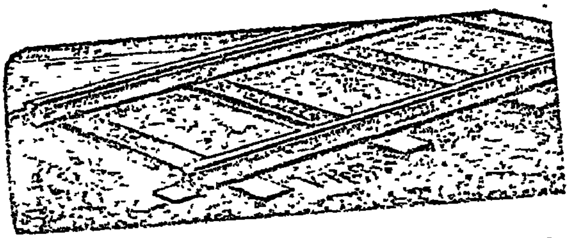


Figure 54 shows the new type of sleepers which has been adopted by the Décauville Company as adding materially to the strength of the tramway.

These sleepers project from three-fourths of an inch to 6 inches (0·019 to 0·150 metres) beyond the rails, thus giving the line a much wider base of support. It is found that the effect of this is to increase the weight which can pass over the rails with safety by nearly one-half.

The distance between the sleepers varies with the gauge and the weight which the railway is constructed to carry. There are usually six sleepers to every section, 16½ feet (5 metres) long; this gives a distance of about 39 inches or 1 metre between the sleepers, as the last sleepers are not quite at the end of the rails. Where extra strength is required, eight sleepers support each section, 16½ feet (5 metres) long.

Curves of radii of 13·12, 19·68 and 26·24 feet (4, 6, and 8 metres) are constructed for rails weighing 8·75 lbs. per yard (4·50 kilos per metre) and for gauges up to 23·62 inches (0·60 metres). On curves of from 26·64 to 32·80 feet (8 to 10 metres) radius the outer rail is raised 0·79 to 1·18 inches (2 and 3 centimetres). This super-elevation is continued for a short distance on the straight portion, the amount of the rise being gradually diminished. The radii of the curves sent with heavier rails and for wider gauges is not specified.

Crossings, switch-boxes, points, turntables, etc., are also made to suit the different classes of railways made. Portable weighing machines and cranes on special trucks are also made.

§ 53. A large variety of trucks specially adapted for the different kinds of traffic for which light railways may be used are also made. Those used at Changa Manga for the transport of fuel are shown in figures 55 and 56 below.

FIG. 55.

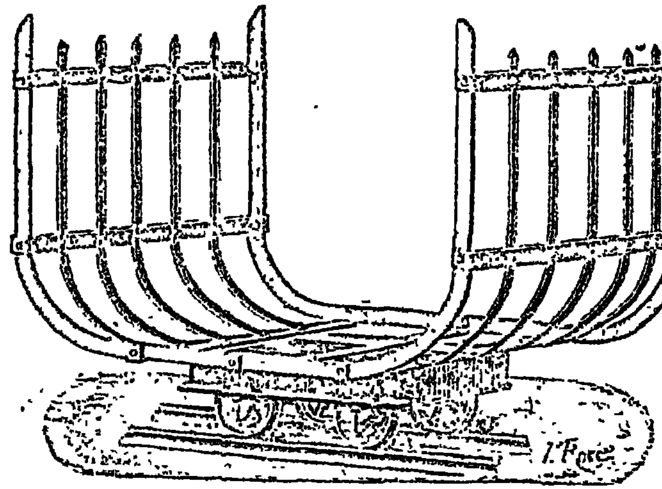


FIG. 56.

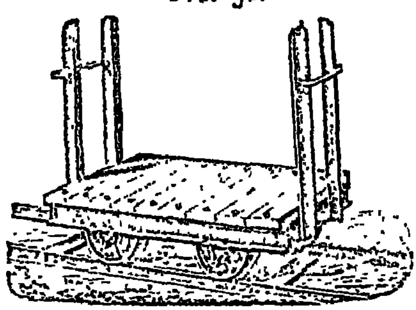


Figure 55 shows the old type of truck, and figure 56 the new type of truck used for the carriage of fuel at Changa Manga. Figure 55 is drawn to a much larger scale than figure 56, as the former is but little longer than the latter.

That shown in figure 56 is especially constructed for the carriage of fuel, while that shown in figure 55 is meant for the carriage of hay or straw, and its framework has been found not to be sufficiently strong for the carriage of wood; it is liable to be bent and broken. The truck shown in figure 57 is better suited for carriage of fuel.

FIG. 57.

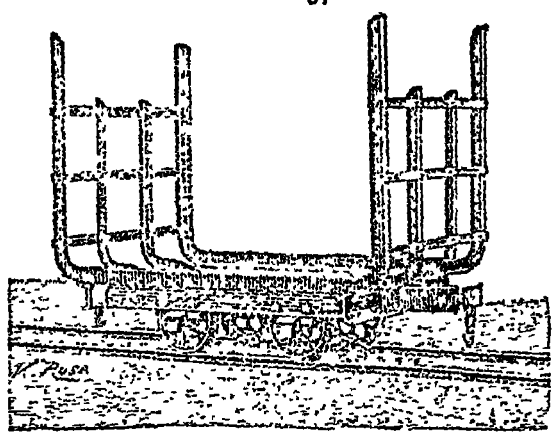


Figure 57 shows a specially strong truck constructed for use in Australia, which is better suited for the carriage of fuel than either of those figured above.

Wagons for the carriage of logs consisting of a pair of trucks furnished with swivel forks, thus forming a bogie for holding the logs, similar to those made by Messrs. John Fowler and Son, are also constructed—*see* fig. 50, page 76.

Special axle-boxes, suitable either for oil or grease, are constructed. The wheels are fixed on to the axle bar and rotate with it. The axle-boxes are fitted with springs when specially ordered. For axles of which the diameter does not exceed 1·38 inches (35 millimetres) the "Panama" axle-box is recommended. In this type of axle-box three strips of rattan cane, bent so as to fit the axle-box, rest on the journal of the axle and dip into the oil reservoir below. The oil rises in the rattan cane by capillarity, and it is claimed that the quicker the wheels rotate the greater the supply of oil. Only pure oil reaches

the journal. It is stated that the pores in the cane do not become choked with dirt.

For axles of a greater diameter than 1·38 inches (35 millimetres) this type of axle-box is not suitable, as it is found that a sufficient quantity of oil does not reach the journal; and for such axles the oil reservoir should be below the axle (*see* figs. 58, 59, and 60, pages 83 and 84) and the oil supplied to it by means of a cotton pad, which is kept firmly pressed against the undersurface of the journal by means of two springs; the centre part of the bottom of the reservoir is also raised so as to come nearly in contact with the journal itself.

FIG. 58

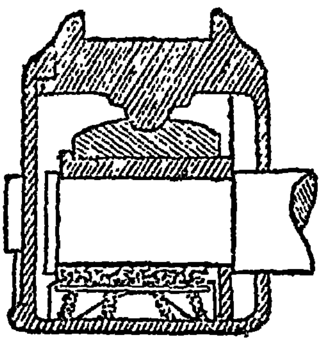


FIG. 59.

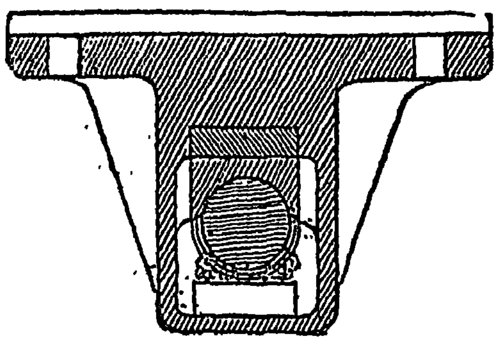


Figure 58 is a longitudinal section through an axle-box suitable for the use of oil or grease.

Figure 59 is a cross-section through the same.

FIG. 60.

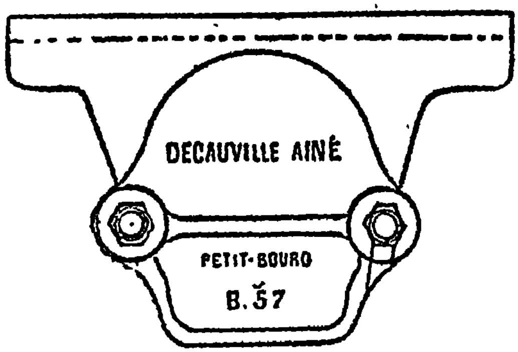


Figure 60 is a side elevation of the same axle-box.

Brakes.—Brakes, worked either by hand or by means of a vertical screw, can be fitted to any of the trucks, and are usually constructed so as to bear on all four wheels at once.

FIG. 61.

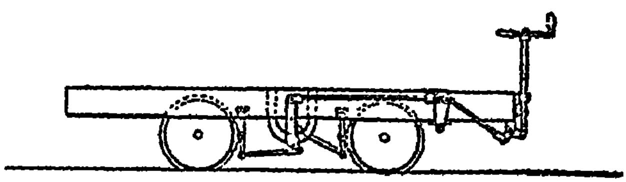


Figure 61 shows a simple brake worked by screw power, which can be fitted on to any truck.

The brakes are put on by means of the screw which brings the blocks of wood up against the undersurface of the wheels. This class of brake is much more powerful than an ordinary hand-brake.

§ 54. PERMANENT TRAMWAYS IN INDIA—LAMBATACH TRAMWAY.—The first forest tramway constructed in India was made at Lambátach (elevation 7,000 feet) in the Jaunsar Forest Division of the North-Western Provinces in 1871. It was used, from June 1872 to March 1873, in connection with the transport of sleepers from the forest where they were cut to the head of the slide down which they passed to the Pabar river below; the fellings then passed to another valley and there was no further use for it.

The length of the tramway was 5,188 feet. The longitudinal rails used were of wood, 5 inches wide and 4 inches deep. On the straight portions of the line the rails used were 12 feet long, but on the curves, short pieces, 3 feet long, were used. The rails were laid on wooden sleepers in which notches were cut to receive them, the rails being kept in position by small wooden wedges (*see* fig. 63, below), one sleeper was placed under the middle of each rail and one close to each end to support their abutting ends. The sleepers were embedded in the ground, so that the longitudinal rails rested on the ground surface. The short rails, of which the curves were made, are supported near each end only.

FIG. 62.

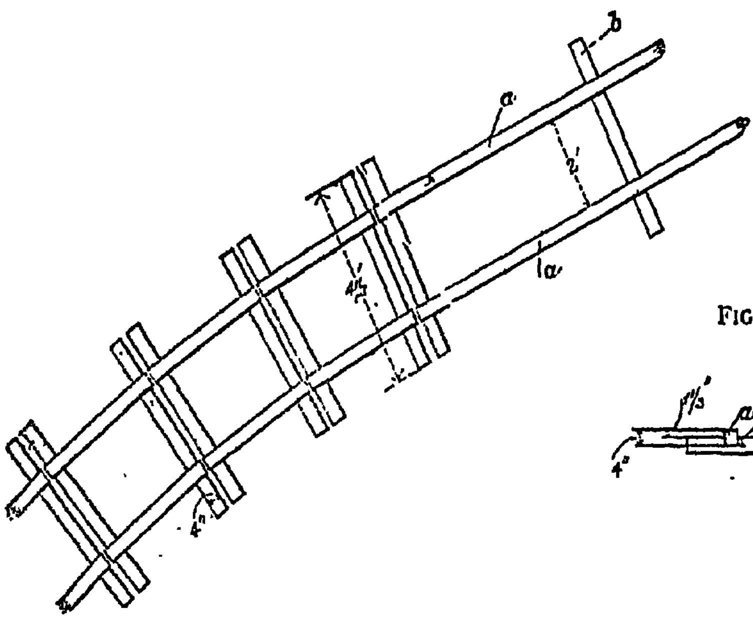


FIG. 63.

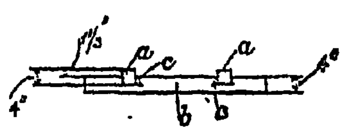


Figure 62 is a plan of part of a curve on the Lambatach Tramway; the radius of the curve is 35 ft.; a, a *are the rails;* b *the sleepers to which the rails are fastened. Scale* = $\frac{1}{48}$. *(Drawn by Mr. J. M. Braidwood).*

Figure 63 is a cross-section of the tramway, showing how the rails (a) *are fastened into notches cut in the sleepers* (b) *by means of wedges* (c). *Scale* = $\frac{1}{48}$. *(Drawn by Mr. J. M. Braidwood).*

The tramway was made very roughly, as it was only required for one year's working. The sharpest curve on the line had a radius of 35 feet. The gradient of the tramway was very low and fairly uniform throughout. The difference in level between the upper and lower ends of the line was only 70·5 feet, so that the mean gradient for the whole line was approximately 1 in 69, or a little less than 0·50 degree. There were no up-gradients on the line. The trucks used had only one pair of wheels, to allow of their going round the sharp curves on the line; a labourer maintained the balance of the truck. Trucks with a single pair of wheels can only be used on tramways where the gradient is uniformly low, as it is difficult to control the balancing and the speed of the trucks on a steep gradient.

The trucks cost R87 each, the axles and wheels being made of iron, and the body of wood. The load of each truck was twelve broad-gauge sleepers, weighing 1,785 lbs. The loaded trucks were taken down the line by one man, who could make four trips a day over the whole length of the tramway (5,188 feet). Three pies per sleeper was paid for taking a sleeper along the tramway.

The total cost of the tramway, including the purchase of ten trucks, was R2,236, and the cost of repairs R46. The net saving due to the introduction of the tramway was R1,400. When the tramway was dismantled, the trucks were practically as good as when they were bought and have since been used on other works.

A temporary tramway, which is taken up annually, similar to that described above, is now used at Dakhpathar on the Jumna, to carry the sleepers which are caught by the boom to the temporary depôt on the banks of the river, out of reach of the floods. The length of this line is about 400 feet. The trucks bought for the Lambatach tram-line are used, and the motive power is man.

§ 55. MANDHOLE TRAMWAY.—A tramway similar to that laid down at Lambatach was constructed at the end of 1871 and opened to traffic early in 1872 at Mandhole in the Jaunsar Forest

Division. The rails were made of chir (*Pinus longifolia*) cut into 12-foot lengths, the rails being 5 inches wide and 4 inches deep. They were laid on deodar sleepers, 4½ feet long, 5½ inches square, placed two feet apart. The space between the sleepers was filled in with ballast up to the level of the longitudinal rails. The inner edges of the rails on all curves and inclines were lined with hoop iron. This was fastened to the rails by screws placed at intervals of one or two feet. The addition of this strip of iron was found to preserve the rails very materially.

The trucks used had four wheels, and cost, delivered at Mandhole, R113 each. The wheels and axles were of iron, and the remaining portions of wood. Each truck could carry twenty-two broad-gauge sleepers, weighing 3,273 lbs., and required three men to work it down the tramway, which was 6,608 feet long. These men could make three trips by day and two by night. In addition to the three men who worked the trucks down, it was found necessary to keep two gangs of men on the steepest inclines in order to let the trucks down these slowly. The difference in level between the upper and lower ends of the tramway was 367 feet, giving a mean down gradient of 1 in 17·7, or about 3¼ degrees. The steepest down gradient on the line was 1 in 6·37, or a little more than 9 degrees. This gradient was found in practice to be too steep to allow of the trucks being worked down without the help of extra men to retard the downward velocity of the truck.

The tramway was either level or had a down gradient with the exception of a length of 700 feet, where up gradients of 1 in 66 and 1 in 200 were rendered necessary by the configuration of the ground. The direction of the line was fairly straight and no sharp curves were necessary.

A wooden brake could be applied to the back wheels of the trucks by means of a long wooden handle, but this was not sufficiently powerful to check the speed of the loaded trucks moving down the steepest inclines on the line.

§ 56. ANDAMANS TRAMWAY.—Before Fowler's tramway was introduced into the Andamans, Mr. Chester, now Conservator

of Forests, laid down a line of wooden rails in the Anikhet valley. The rails were laid 2 feet apart. The rails were of pyinma (*Lagerstræmia hypoleuca*) which was found to be the most suitable, as it could be easily bent into the curves that were required after having been steamed. The sleepers were made of any hard wood and were laid 3 feet apart. The rails were fastened to them by nails 8 inches long, driven in until the heads of the nails were buried half an inch below the surface of the rails. The sleepers were 5 feet long by 5 inches wide by 3 inches deep, and the rails 12 to 15 feet long, 3 inches wide and 4 inches deep. Mr. Buchanan, late Extra Deputy Conservator of Forests in the Andamans, is of opinion that some time and expenditure would have been saved in repairing the line had shorter lengths of rail been used, as the lifting and replacing of the worn portions of the line would have been easier and less steaming and bending of the rails round curves would have been required.

Trucks similar to those used on Fowler's tramway were used, except that the flanges of the wheels were deeper: they were 3 inches deep, so as to give them a better grip on the rails. The castings of the wheels and axle-boxes were made locally at a comparatively small cost.

§ 57. PORTABLE TRAMWAYS IN INDIA.—The information with regard to the laying of the way of portable tramways, the most suitable gradients, curves, etc., has been extracted from the reports on the working of the several lines which will be found in Appendix II to this volume.

CHOICE OF GAUGE.—The experience gained on the working of the portable tramways in India up to the present date shows that where timber is to be transported the gauge should not be less than 24 inches. In the case of lines constructed for the carriage of fuel only, where the load per truck will be smaller, a gauge of 16 inches has been found to work well.

The gauge of the tramway will, in the first instance, depend upon the nature (more especially the weight per unit of volume) of the produce to be carried over it, and then upon the sharpness of the curves on the line. The heavier the load per

truck, the heavier must the rails of the tramway be, and as the gauge of portable tramways increases with the weight of the rails used in their construction, it follows that the heavier the forest produce per unit of volume to be carried over the line the broader must be the gauge. Loaded trucks passing round sharp curves are much more easily derailed if the gauge is small.

The broader the gauge the greater is the initial cost of the way, the rolling-stock, the preparation of the track, the cost of the up-keep of the line and the cost of shifting it from one place to another.

The gauge chosen for the Andamans tramway and the Anamalai and Nellore tramways in the Madras Presidency was 24 inches, while that of the Changa Manga line in the Punjab was nearly 16 inches (0·40 metre). Large logs are carried over the Andamans and Anamalai lines, the load per truck varying from 1 to 3 tons. The Changa Manga and Nellore lines were constructed for the carriage of fuel only, and the load per truck varies from 2,240 lbs. (Nellore) to 3,198 lbs. (Changa Manga).

The gauge of the Darjeeling-Himalayan Railway from Siliguri to Darjeeling is only 24 inches; the rails weigh 41¼ lbs. to the yard and are laid on wooden sleepers. The trucks and passenger carriages project about 18 inches beyond the wheels on either side.

The gauge of the tramway in the Sihlwald near Zurich in Switzerland is about 24 inches (0·60 metre). Both timber and fuel are carried over this line.

It would be advisable in future to adopt 2 feet as the gauge for forest tramways all over India and Burma, and to use rails of different weights according to the weight of the load which is to be carried over them. The advantages of a uniformity in gauge are too obvious to require enumeration.

§ 58. WEIGHT OF RAILS.—The weight of the rails used depends upon the weight of the forest produce to be carried over the line and the distance between the sleepers which sup-

port the rails. The heavier the load per truck, the heavier, as a rule, must be the rails used. The effect of putting the sleepers closer together is to increase the weight that the rails can carry without being strained. The heaviest load to be carried over the line determines the weight of the rails.

For timber, where the load per truck is between 1 and 3 tons (2,240 to 6,720 lbs.) including the weight of the truck (which on the Andamans portable tramway weighs half a ton), rails weighing 18 lbs. per yard, supported on sleepers placed 3 feet apart, have been found sufficiently heavy.

In the case of fuel, where the load per truck is from $\frac{3}{4}$ to 1 ton (1,680 lbs. to 2,240 lbs.), exclusive of the weight of the truck, rails weighing 10 lbs. to the yard supported on sleepers placed 3 feet 9 inches apart have proved satisfactory.

The line must of course be properly laid and supported; if the line is badly supported, the loads noted above will strain the line and bend the rails out of shape very quickly, thus making the working of the tramway difficult.

If the rails used are too light, they will get strained by the traffic that passes over them, and this will lead to frequent derailments of the loaded trucks. The length of the sections used varies with the weight of the rails. The sections should be easily portable from one place to another, consequently the heavier the rails the shorter should be the sections. In the lighter types of Fowler's portable tramways the rails are 15 feet long, while in the semi-portable lines the rails are usually made in lengths of 21 feet, and are then somewhat heavy to carry from one place to another, unless the sleepers are separated from the rails.

§ 59. CURVES.—Sharp curves should be avoided wherever possible, on account of the risk of derailment, the increased wear and tear on the way and rolling-stock, and the inevitable strain on the tractive power, which they involve.

Curves on or to bridges should be avoided and the approaches to either end of a bridge should be, as far as possible, dead level.

The trucks used in the Andamans on forest tramways are made on rigid frames which give no play to the axles of the wheels, bogeywise.

The radius of the sharpest curve round which it is possible to work a loaded truck with safety on a portable tramway depends upon the gauge of the line, the kind of truck used, the character of the load, and the nature of the motive force.

If the curve is very sharp, the trucks will be easily derailed while passing over it: the narrower the gauge the more easily will the loaded truck overturn.

The wider the platform on which the load rests and the nearer to the ground the centre of gravity of the loaded truck is, the less easily will it be capsized when passing round a sharp curve.

The character of the load affects the position of the centre of gravity of the loaded truck and thus its stability; compare, for example, a truck loaded with fuel, in which the fuel is stacked to a height of 6 feet above the platform of the truck, with a truck carrying a log, the upper surface of which is only 3 feet above the platform. Experience has proved that it is more difficult to work a long log round a curve than a short one. As regards the tractive power, a loaded truck can be worked round a curve by hand which would be derailed if drawn by bullocks.

The experience gained on the Andamans portable tramway, over which the logs were worked by men or buffaloes, shows that, consistent with smooth and economic working, no curve should have a radius of less than 50 feet, even at the cost of increasing the gradient slightly; and that under no circumstance should the radius of the curve be less than 30 feet.

The outer rail of the curve, no matter how gradual it may be, should always be slightly raised. The sharper the curve the more should the outer rail be raised. In the Andamans the extent of the raising is not regulated by any formula, but is done by eye.

The working on the Anamalai timber portable tramway confirms the Andamans' experience. Curves with a radius of 18

feet proved much too sharp and their use at first resulted in the constant derailment of the trucks when going round them. By raising the outer rail $1\frac{1}{2}$ inches above the inner one, by carefully ballasting the line, and by the addition of a second rail along the inner side of the curve, so as to increase the grip of the flanged wheel on the rails, the curves have been made practicable for bullock power. At Changa Manga, where fuel is exclusively carried over the line, the sharpest curve consistent with smooth and economical working has been found to have a radius of 30 feet, when bullock power is used. Loaded trucks can be worked, by hand, round a curve with a radius of only 10 feet.

The sharpest curve on the Darjeeling-Himalayan Railway has a radius of $69\frac{1}{2}$ feet.

§ 60. GRADIENTS.—The *ruling* gradient (see Volume II, page 34) for portable tramways depends, as we have already seen (page 63, § 43), upon the tractive power for ascents and the brake or retarding power for descents. In practice, however, while the brake power which can be applied determines the ruling gradient for descents, the actual up gradients which are allowed on a tramway are determined on economic grounds. The up gradient must not exceed that up which loads can be drawn economically with the available tractive power. This gradient depends upon the weight of the heaviest load to be carried, the nature of the tractive power available, and the actual cost of carriage by the ordinary methods of transport in the district in which the tramway is constructed. On the Anamalai tramway in the Madras Presidency it was found cheaper to carry the heaviest logs to be exported in carts along the existing cart road than to haul them up the steepest inclines on the tramway as originally laid down.

§ 61. The best gradient which can be obtained for a tramway is a constant and gentle *down* one, of such intensity that the loaded trucks can move slowly down it, in virtue of their own weight. This down gradient must be sufficiently low to allow of the speed of the descending loaded trucks being controlled by brakes.

If the country will allow of a tramway being constructed with a constant down gradient, the track should be aligned with a constant gradient of 2 in 100 (1° 9′) for the transport of timber and 3 in 100 (1° 43′) where fuel only is to be carried over the line, and these gradients should not be departed from if practicable.

If the gradient exceeds 2 in 100 in the case of timber or 3 in 100 in the case of fuel, brakes will be required to check the speed of the descending loaded trucks, and the steeper portions of the lines should, where practicable, be succeeded by nearly level sections.

The ruling gradient depends upon the nature of the load, its weight and the brake power available.

In the case of the Andamans tramway, where logs weighing as much as 3 tons each were carried over the line, the best down gradient was found to be 2 in 100 (1° 9′). On this gradient the trucks would just move slowly by themselves, while they could be held under perfect control by a single brakesman. The gradient was never allowed to exceed 3 in 100 (1° 43′) unless each truck was fitted with the brake shown in detail in figures 64, 65 and 66, page 102.

Loaded trucks fitted with this brake were taken down short distances with a gradient of 4 in 100 (2° 18′) and even 5 in 100 (2° 52′); but, as Mr. Buchanan, Extra Deputy Conservator of Forests, remarks, taking the loaded trucks down such steep inclines was always nervous work. The best gradient on the Sihlwald tramway (see Appendix III, page 361 to this volume) was found to be 2 in 100 (1° 9′) or 3 in 100 (1° 43′). This tramway was used for the carriage of logs as well as fuel. The logs rested on two trucks, the load on the pair of trucks varying from 4,517 lbs. to 6,776 lbs.

As many as six trucks loaded with fuel were taken down by one brakesman controlling three brakes placed on the three last trucks. The total weight of the firewood in these trucks was 19,800 lbs. The details of the brake used are shown in figures 67, 68 and 69, pages 103, 104 and 106. The gradient of the lines was never allowed to exceed 5 in 100 (2° 52′) as a general

rule, though trucks laden with fuel have been taken down considerable lengths of line with a gradient of 7 in 100 (4°); but this gradient was found to be too steep and the trucks could only be worked down it by specially selected and experienced men. In a most exceptional case, single loaded trucks have been worked down over a distance of 200 feet with a gradient of 11 in 100 or (6° 43′), but it is very difficult to control the speed of the loaded trucks on such steep gradients even with the best brakes.

§ 62. In India as a rule the physical features of the ground will seldom allow of the most economical gradients for a tramway being selected, and both up and down gradients will, as a rule, be found necessary.

In the Anamalai line the total rise in about 5 miles was 666 feet, but this is an exceptional case. A tram line should have a slight down gradient or be made level whenever the natural obstacles to be overcome allow of this being done, and the up gradients should never exceed 3 in 100 (1° 9′) for buffaloes or 2 in 100 (0° 43′) for men, except for short distances where loads weighing one ton or more are to be transported.

The experience gained in the Andamans show that where loads of between 1 and 3 tons have to be carried over a tramway, the up gradient should never exceed 2 or 3 in 100, as if this slope is exceeded a greatly increased motive force will be required to haul the loaded trucks up the line. Coolies cannot be expected to push even lightly laden trucks up gradients exceeding 3 in 100 (1° 43′), while buffaloes at the rate of one animal to each ton of wood carried can only just haul the laden trucks up an incline of 5 in 100 (2° 52′).

The experience gained on the Anamalai tramway again confirms the Andamans' experience as regards the *ruling* up gradient, as it was found that the maximum gradient up which a pair of bullocks could haul a log weighing 2 tons should never exceed 1 in 15 (3° 49′), and if possible should be kept as low as 5 in 100 (2° 52′); while for the economic working of the line Mr. Cherry, Conservator of Forests, Madras, is of opinion that the ruling gradient should be reduced still further

until a pair of bullocks could haul logs weighing 2 or 3 tons (54·64 or 81·96 maunds) up the steepest incline on the line.

On the Sriharikota fuel tramway, where the trucks carried loads of ¾ to 1 ton (1,680 lbs. to 2,240 lbs.), the maximum up gradient for lengths not exceeding 200 feet was fixed at 1 in 12 (4° 45′).

§ 63. PREPARATION OF THE TRACK.—The centre line of the tramway is marked out by pegs in the same way as that of a road or path is laid out on the ground (see Volume II, page 68, *et seq.*), and the curves are correctly set out. The track is then cut out to the required width and the sleepers and rails laid on it.

The track should, if practicable, be made uniformly 6 feet wide, so as to allow of men and animals passing the trucks at any point on the line. The track should be slightly wider on embankments so as to prevent their edges being pushed down by the men and draught animals which pass over them; it should also be made slightly wider round curves. Where the track passes through difficult ground its width may be reduced to 4 feet, in order to lessen the initial cost of making the track.

To ensure the smooth working of the line, it is most important that the track should be solidly and carefully prepared, so as to afford an adequate support to all parts of the line that is laid upon it.

In the Nellore district, Madras Presidency, where the tramway had to be laid on pure sand, it was found necessary to let the steel sleepers into wooden ones, in order to keep the line stable; three sleepers were placed under each section 15 feet long.' The steel sleepers had to be bolted to the wooden ones before perfect rigidity was obtained. The steel sleepers supplied with the portable line soon became displaced if laid directly in the sand.

§ 64. LAYING THE LINE.—The method of laying the line differs with the type of tramway used. In the case of the *Décauville* system, and others in which the rails are rigidly fixed to the sleepers, the laying of the line consists of placing the

sections on the prepared track and fastening the ends of the adjacent sections together with bolts and nuts.

At Changa Manga, the sections of the line are laid on the prepared track, but are not bolted together.

In the case of *Fowler's* portable tramway, systems A and B (see §§ 46, 47, page 68, *et seq.*), where the rails are fastened to the sleepers by hook-bolts, the sleepers are first laid on the track at the required distances apart, and the rails are fastened to them by the hook-bolts. Great care must be taken to see that the bolts are very tightly screwed up, so that the rails cannot by any possibility become displaced. If the screw-bolts are properly tightened the joints become the strongest parts of the line.

In the case of the Anamalai tramway, the first quarter of a mile was laid in three days by inexperienced labour, and no difficulty whatever was experienced either in fixing the rails on to the sleepers or in putting the trucks together. The sections of the line were easily moved from one place to another by coolies under the superintendence of a forest guard.

In the Andamans, system D D of Fowler's portable tramway was used, and the procedure finally adopted for laying the line is as follows. The sleepers are first placed on the track 3 feet apart from centre to centre. One rail is laid first, and after this has been inspected and such corrections made as may be found necessary in the levels and curves, the sleepers are placed exactly at right angles to the rail and bolted to it. The companion rail is then fixed in position at the opposite ends of the sleepers. The object of laying one rail first is to avoid the narrowing of the gauge that would inevitably ensue if both rails were laid at once, a correction found necessary, and the curve altered accordingly. The narrowing of the gauge would cause the trucks to jump and leave the rails at the point where the narrowing had taken place.

The slots in the fish plates, by which the ends of the rails are fastened to each other, are purposely made half an inch longer than the diameter of the bolts by which they are fastened to the rails. Each rail, as it is laid should be pulled out so as to

leave a small space between the ends of the rails, to allow for the expansion of the metal that will occur in hot weather; the shape of the slots in the fish plates allows of this being done. The joints of the rails were never laid opposite to each other, as is usually the case in railways. The bolts passing through the fish plates and rails must always be screwed up very tight, and if this is done the joints between the rails become the strongest points. The rails are not joined over the sleepers, because if this is done it is impossible to bolt the clips down to the sleepers owing to the fish plates being in the way.

When a rail has to be bent into a curve, the rail-bender should be applied to the rail at every 9 or 12 inches of its length, producing at each point an almost imperceptible bend but along the whole rail a decided regular curve. The bending of the rails should be done away from the joints as much as possible. If a joint must be bent to preserve regularity in a curve, the fish plates should be beaten to shape first and then clamped to the bent ends of the rails.

As soon as the sleepers are laid they should be packed with stones. This is always necessary, but particularly so on an unmetalled track. The packing is done by means of rammers and packing hammers. Besides packing under the sleepers much additional stability can be given to a line on an unmetalled track by laying billets of wood under the rails alternating with the sleepers. Where the ground is naturally wet or soft the line should be laid on billets of wood so as to make the way stable.

Sidings should be constructed at every half mile or mile along the line to allow of trucks and trollies passing each other.

Loop lines may be constructed at the ends of the tramway, where practicable, instead of sidings, the length of the loop being sufficient to accommodate the largest number of trucks which is ever likely to be shunted on to it.

§ 65. In the Andamans, experience showed that if the track is not metalled, billets of wood passed crosswise under the rails are necessary to make the line stable. Metalling is not essential on a tramway over which the trucks are moved by

bare-footed men; but it is always desirable, as it improves the drainage, facilitates the work, and lessens the cost of maintenance of the track. Where stone is available all along the line, as it usually is in hill forests, the cost of metalling the actual track itself will not be very much and will render the working of the tramway much more satisfactory. Where buffaloes or bullocks are used for draught purposes with Fowler's system D D tramway, the track must be roughly metalled. The metal need not be broken small but must be well rammed and its surface strewn with gravel or sand, so as to consolidate it properly.

§ 66. DRAINAGE OF THE LINE.—A good system of drainage is always important, but especially so in a country where the rainfall is heavy, in order to keep the track on which the tramway is laid as dry and as unyielding as possible. A thorough system of drains is essential to the stability of the track where the soil as clayey and the track unmetalled. In the Andamans, in cuttings, a large central drain between the rails has been substituted for the usual side drains.

A broad, fairly deep, drain along the inside of the track, with cross drains at frequent intervals, is one of the best ways of keeping the track dry. This drain should be lined with stone if there is any chance of the water percolating into the ground and causing the hillside to slip.

If Fowler's tramway system D D (the Andamans type) is used, small drains should be cut between the sleepers leading out under the rails, as the men who pack the sleepers are apt to earth up the rails along the outside and the rain then accumulates between the sleepers and forms puddles.

§ 67. PRESERVATION OF THE LINE.—Constant use keeps the rails in a fair state of preservation, but in the Andamans it has been found advisable to clean and tar the rails and sleepers periodically. The sleepers and rails are well heated and scaled until all the rust has been removed and then smeared with hot tar. Where a cart road crosses the tramway, or where logs are dragged across it, the line itself should be protected by baulks of timber, placed alongside of the rails firmly

embedded in the ground and projecting slightly above the level of the rails.

§ 68. ROLLING-STOCK.—On the Anamalai timber tramway, bogie trucks in pairs (see figure 50, page 76) were used for the transport of the logs extracted. The trucks came out from England in parts, which were easily put together; the trucks were capable of standing any amount of rough usage and were, if anything, stronger and heavier than was necessary. The heaviest load placed on them so far is 3 tons.

In the Nellore district, where tramways for the carriage of fuel have been laid down, the trucks used were sugar-cane wagons, type *J.* (figure 49, page 75). These trucks carry from ¾ to 1 ton of fuel and have worked satisfactorily.

On the Changa Manga fuel tramway, the two types of trucks used are shown in figures 56 and 56, page 81. The framework of the truck shown in figure 55 was found too flimsy for the transport of fuel and was constantly being broken, and so when new trucks were required those shown in figure 56 were purchased. The old type of truck weighs 636 lbs. and can carry 100 cubic feet stacked of thick (*i.e.* over 2″ and up to 10″ diameter) billets of fuel, which weigh 3,198 lbs. The new type of truck carries 80 cubic feet stacked of fuel of thick billets.

In the Andamans only wheels, axles and axle-boxes were bought, and specially strong heavy *single* trucks were made locally of wood. These trucks consist of a framework of timber, (see figure 64, page 102) strengthened by two iron tie-rods (*S-S*, figure 64, page 102) carrying a strong wooden platform. Oil axle-boxes are fastened to the underside of this framework to receive the journals of the axles of the wheels. The wheels are slotted on to the axle and cannot move independently of it; a flat iron plate is fixed on to the top of the wooden platform, in the centre of which is a hole for receiving the leg of an iron frame or *T*-shaped fork. This frame pivots in the hole and rotates on the ring plate (see figure 50, page 76) and supports the ends of long logs when two trucks have to be employed to carry a single piece of timber, so as to allow of the trucks

passing round the curves independently of the logs resting on them. In the Andamans the logs were all transported on single trucks.

Experience in the Andamans shows that at least two light hand trollies are necessary on every tramway for inspection purposes.

The inspecting officer riding on his trolly and keeping his eyes fixed on the rails can mark all the defects in the line as he passes over it, and a road overseer with a gang of men following him can remedy all the defects noted, and in this way all conspicuous irregularities in the line will rapidly disappear. The trolly consists of a light framework with a moveable back for the seat. Two handles for the trollymen are provided, which can be inserted into slots at either end of the trolly as may be necessary.

The wheels are made separately from the body of the trolly, so that when the trolly meets the trucks, it can be taken to pieces and lifted off the line so as to allow the laden trucks to pass by.

§ 69. BRAKES.—Brakes are necessary on all timber tramways where the gradient exceeds 2 in 100 ($0°43'$), and on fuel tramways when the gradient is more than 3 in 100 ($1°9'$). In the case of timber trucks worked singly, brakes should be fitted to every truck. Where the trucks are used in pairs, the hinder truck should be fitted with a powerful brake.

As regards fuel trucks, if they are worked down singly, each truck must be provided with a brake, but, where, as is usually the case, a number of trucks are worked down together, a certain number of the hindermost trucks should be provided with powerful brakes.

The brakes used on the Anamalai tramway were not found sufficiently powerful to control the loaded trucks when descending the steep gradients on the line, and no satisfactory brakes have yet been obtained. This points to the advisability of reducing gradients to the limits proposed by Mr. Cherry (see page 94, § 62.)

§ 70. In the Andamans, screw brakes were not considered satisfactory, as the mechanism was apt to be in the way and, if damaged, could not be repaired locally; and, moreover, such brakes would have been more expensive in the first instance.

Lever brakes, with the handles below the platform of the trucks and still within easy reach of the brakesman, were found absolutely necessary. It was also found to be a *sine quâ non* that the brake should be simple, with few parts or joints, and yet effective. Figures 64, 65 and 66 show the construction of a powerful double brake designed by Messrs. Fordyce and Buchanan, which has been found to work satisfactorily, and has now been generally adopted in the island.

The brake is simple and has no joints. It is worked from the side of the trucks. No brakes applied at the end of the trucks have been found effective, and now when the trucks are loaded the men are forbidden to go in front of them.

The principle of the brake is a *jam.* By pressing down the lever *D* (see figure 64, page 102), the cross piece *M M* tends to become horizontal and thus presses the blocks of wood *C C* (figure 64) against the rims of the wheels of the trucks, and so retards their motion. The force with which the brakes are put on can be increased materially by placing a pole into the loops at *R R* welded on the lever *D* in order to lengthen the lever by which the force is applied to the brake.

In order to get an even pressure on the wheels, the cross-bar *M* (figures 64, 65), which is shown in detail in figure 66, is given a little play by the slot *E F*, through which the axle pin passes, being made ¼ inch longer than the diameter of the pin.

Figure 65.—The pin F *is shown in detail; it is square where the arm* D *fits on to it, but round where it passes through the brackets* K *and* L *so as to allow of its rotating easily. It is also square in section where the cross piece* M M *fits on to it. The end of the pin* F *is at* Y: *the rim of the wheel on to which the brake presses is shown at* G G.

B B *and* C B *are parts of the framework of the truck on to which the iron flanges supporting the pins* F Y *are fastened. A pin* P *keeps the lever on the head of the pin* F Y.

Figure 66 shows in detail the construction of the cross piece to which the actual brakes are fastened. (Scale 1 inch = 1 foot.)

FIG. 64.

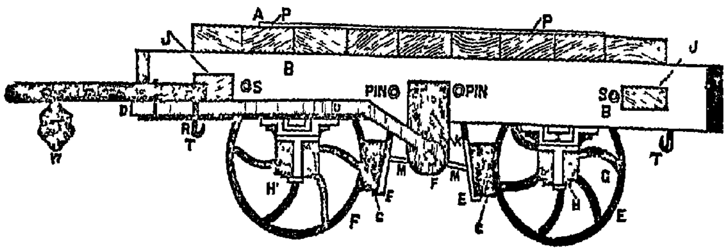


FIG. 65.

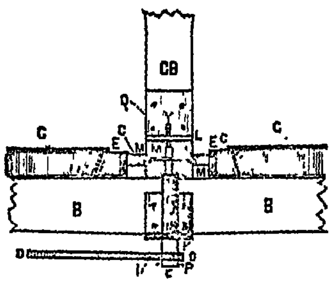
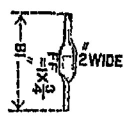


FIG. 66.



Figures 64, 65 and 66 show the construction of the brake used on timber trucks on the Andaman Islands portable tramway.

Figure 64 is a side elevation of a truck, used for the transport of logs in the Andaman Islands, to show the brake in use there.

Figure 65 is a part plan of an inverted truck, after the platform of the truck has been removed, to show how the brake is fastened to the framework of the truck.

Figure 66 shows in detail the cross bar M M *of figures 64 and 65.*

Figure 64.—A *is the iron plate to which the swivel fork is fastened.* P P *are the planks which form the platform of the truck itself.* B *is one of the side beams of the framework to which the platform of the truck is fastened.* J J *are two of the cross beams of the framework.* S S *are tie-rods added to further stiffen the framework of the truck.* H H *are the axle-boxes, in which the journals of the wheel rotate. They are fastened on to the undersurface of the longitudinal beam* B. F F *are wheels.* C C *are the blocks of wood which press on the wheels. They are fastened into iron arms* E E, *which revolve about pins bolted to the framework of the truck. These iron arms are joined by a cross bar* M M, *which is shown in detail in figure 66. This cross bar fits on to a pin* F, *which fits into iron brackets* K L *fastened to the framework of the truck. The bracket* L *is not seen in this figure.* D *is the arm of the lever which fits round the pin* F *and by means of which the brake is applied to the wheels. This lever is fitted with two loops* R, *into which a wooden rod can be placed and the power of the lever still further increased.* T T *are the hooks to which the ropes used in dragging the trucks are fastened.*

Figure 65.—The pin F *is shown in detail; it is square where the arm* D *fits on to it, but round where it passes through the brackets* K *and* L *so as to allow of its rotating easily. It is also square in section where the cross piece* M M *fits on to it. The end of the pin* F *is at* Y*: the rim of the wheel on to which the brake presses is shown at* G G.

B B *and* C B *are parts of the framework of the truck on to which the iron flanges supporting the pins* F Y *are fastened. A pin* P *keeps the lever on the head of the pin* F Y.

Figure 66 shows in detail the construction of the cross piece to which the actual brakes are fastened. (Scale 1 inch = 1 foot.)

§ 71. The brake used on the Sihlwald tramway is very simple in construction and is more powerful than the one used on the Andamans line, as it allows of the loaded trucks being worked down steeper gradients with perfect safety.

Figure 67 is a plan of a truck showing how the brake is arranged, and the method of applying the brake is shown in figure 68, which is an end elevation of the framework in which the screw by which the brake is applied works.

FIG. 67.

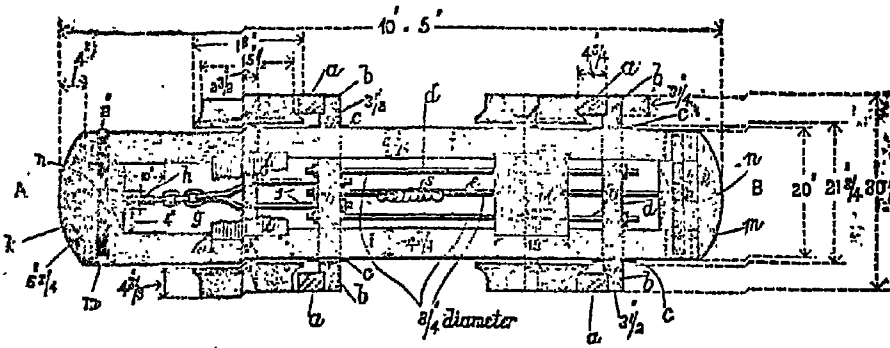


Figure 67 is a plan of a Sihlwald truck to show the arrangement of the brake; the framework on which the timber or fuel rests has been removed; a, a, a, a *are the blocks of wood which pass against the wheels;* b, b *are the bars of wood to which these are bolted;* c, c, c, c *the iron stirrups in which bars* b, b *rest;* d, d *two iron rods connecting the bars* b, b *with each other;* e *the rod furnished with a spiral spring which keeps the wooden blocks off the wheels;* f, f *the rods joined to form a hook to which the chain* g *connecting the brake with the screw is fastened. The chain* g *passes round a grooved wheel* h; i, i *are the longitudinal pieces, and* k, k *the end pieces of the framework of the truck, blocks of wood* l, l *are placed over the axles and halved into the longitudinal pieces* i, i. *A hole (shown in dotted lines) is cut in the end pieces* k, k *to allow of the trucks being coupled together;* m, m *are straps of iron to strengthen the trucks; and* n, n *the holes in which the coupling pins are placed.* (*Scale 2 feet = 1 inch.*)

FIG. 68.

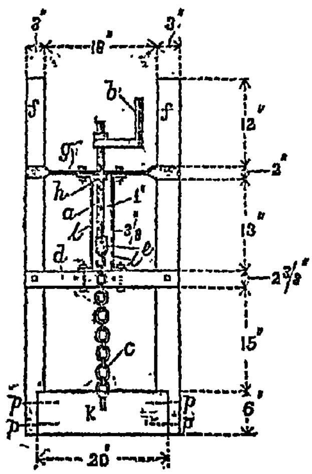


Figure 68 is an end elevation showing how the screw by which the brake is applied is supported. a *is the screw;* b *the handle, by rotating which the screw is raised or lowered;* e *is the block of iron in which the screw ends. This is furnished with a hook which takes the chain* c *which is attached to the brake proper;* d *is a bar of wood tying the two uprights* f, f *together;* g *is a bar of iron bolted on to the uprights and twisted into a horizontal position to take the screw;* h *is a collar through which the screw passes;* k *is the end portion of the framework of the truck* (k, *fig.* 67). (*Scale 2 feet = 1 inch.*)

The framework which carries the timber or fuel has been removed to show the arrangement of the brake. A is the front end, B the back end of the truck. *a, a, a, a* are the blocks of wood which press on the wheels.

These blocks are bolted by countersunk bolts on to the two wooden bars *b, b.* The bars *b, b* rest in iron loops *c, c, c, c* which allow of their moving in a horizontal position. The loops are screwed on to the framework of the truck, which carries the wheels. The two bars of wood are connected with each other

by two iron rods *d*, *d*, ⅝ inch in diameter. Another rod *e* is bolted to the front bar *b*, passes through the back bar *b* and is bolted to the back end B of the framework of the truck. A strong spiral spring is introduced into this rod, which keeps the brakes off the wheels when they are not required. Two rods *f*, *f* are screwed into the front bar *b* of the brake and are joined together and welded into a hook, a chain *g* passing round a grooved wheel *h* connects the brake with the screw (*a*, fig. 68). The wheel *h* is carried by iron brackets screwed on to the framework of the truck.

Figure 68 shows the screw *a* by which the brake is pressed on to the wheels when required. By turning the handle *b* of the screw the blocks of wood are brought into contact and kept in contact with the wheels. The more the screw is turned the greater will be the pressure on the wheels. As soon as the chain is loosened by turning the screw in the opposite direction the blocks of wood are taken off the wheels by the spring (*s*, fig. 67).

The screw ends in a block of iron *c* to the front of which a hook taking the end of the chain *c* attached to the brake is welded. The block and hook allow the chain to clear the horizontal wooden bar *d* which ties the frame together. The framework in which the screw works is made of pieces of bar iron ⅜ inch in thickness and 2 inches wide bolted together.

In the Sihlwald when fuel is transported, six truck-loads of fuel are brought down at one time by one man. The fuel in the trucks measures 694 cubic feet solid and weighs about 19,000 lbs. The three back trucks are furnished with brakes. The brakes are manipulated by one man who stands on a platform attached to the back truck. The brake on the back truck is applied by screw power in the manner just described. The brakes of the other two trucks are furnished with long levers ending in hooks. Cords fastened to these hooks pass over pulleys fixed to a framework constructed on the back truck, and are wound round a drum. The brakes are applied by winding the cords round the drum.

Figure 69[1] shows how the hook lever is fastened to the brake. A spring keeps the brakes off the wheels when the cords (fig. 69) are slackened.

FIG. 69.

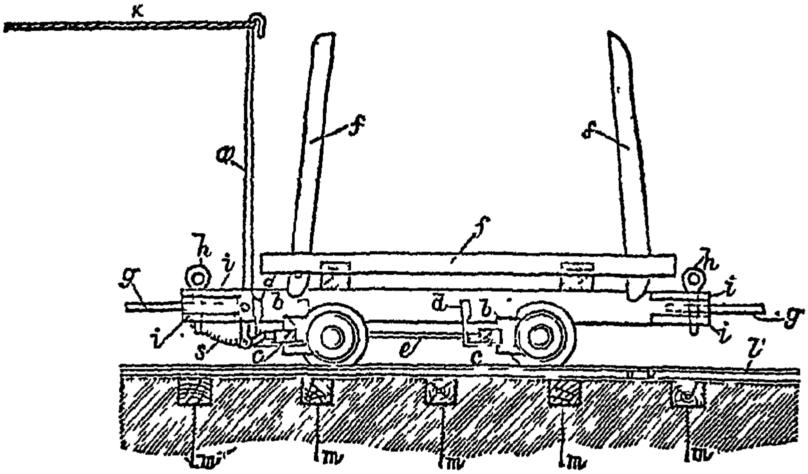


Figure 69 is a side elevation of a truck fitted with a brake applied by means of a long lever; a *is the lever;* b, b *are the wooden blocks which press on the wheels;* c, c *are the wooden bars to which these are bolted.* d, d *the iron brackets which support the bars* c, c; e *the rod (only one is seen) connecting the bars* b, b. *The springs keep the brakes off the wheels when necessary.* f *is the framework to carry the fuel, which fits on the frame which support the wheels;* g, g *are the links by which the trucks are coupled to each other by means of the pins* h, h; i, i *are iron straps screwed on to strengthen the ends of the truck;* k *is the cord which goes to the hindermost truck;* l *is the rail (only one is seen) and* m, m *the wooden sleepers on which the rails are laid. Scale* = $\frac{1}{16}$ *(after Mr. C. Hartmann.)*

The trucks are attached to each other in a very simple manner; a hole 4 inches wide and 2 inches deep is cut in the end of the framework of each truck. Iron bands (*m, m,* fig. 67) 19 inches long 2 inches wide and ½ inch thick are screwed on to the top

[1] Holz-transport in den Stadtwaldungen von Zürich, gezeichnet von C. Hartmann, Forest Assistant, 1886.

and bottom faces of the framework. Holes (*n*, *n*, fig. 67) are bored through these bands and the framework. An iron link is placed in the holes cut and bolts passing through these holes and through the link connect the trucks one with the other.

§ 72. MOTIVE POWER AND LOAD.—It is assumed that the ruling gradients laid down in § 62, page 94, have been strictly adhered to, and that no curve on the line is sharper than that laid down as the minimum in § 59, page 90. Then the actual amount of the load which can be carried over a tramway depends upon the motive and brake power available and the gradients on the line. When long logs have to be transported the sharpness of the curves on the line becomes of importance.

In order that a tramway may be a financial success, the gradients must, as has already been laid down, be so regulated that the load to be transported can be drawn economically with the tractive power available.

Andamans timber tramway.—On the Andamans timber tramway, loads of 1½ tons (3,360 lbs.) kept under perfect control, can be run down gradients of 4 in 100 by four *men*. Where manual labour only is available the most economical load is one ton (2,240 lbs.) so long as the log does not exceed 18 feet in length. Such loads are neither too heavy to be pushed up hill nor to be controlled by four men going down hill. On a level track the most economical load for four men is 1½ tons (3,360 lbs.).

With buffaloes or bullocks, the loads that can be transported over fairly level or up-hill lines may be increased by 50 per cent. On such lines so long as the down gradient does not exceed 3 in 100 (1° 13′) draught animals are better than men. But where the down gradients exceed this amount men are better than buffaloes or bullocks, because the latter can exercise no backward pressure on the trucks going down hill and the entire control of the truck rests with the brakeman. Four men can keep a loaded truck, going down a steep gradient, under far better control than one brakesman who has to guide the buffaloes in addition to manipulating the brake.

In carrying timber over a tramway on a single truck, the log must be very carefully balanced. The centre of gravity of the

log should be slightly in front of the mid-length of the truck so as to prevent the front wheels from jumping off the line in case the truck is inclined to rock.

The carriage of a long log on a single truck round a sharp curve is always risky, as the log has a tendency to oscillate and to throw the truck off the line. The larger end of the log should be placed on the front portion of the truck so as to prevent the wheels jumping off the line. Accidents have hitherto been avoided by insisting upon the loaded trucks being moved round the curves at a walking pace. Long logs should, whenever practicable, be carried on a pair of bogie trucks (see fig. 50, page 76) if there are sharp curves on the line.

The loaded trucks travel at the rate of about 2 miles an hour: an ordinary walking pace should never be exceeded. Four men will push a loaded truck over an ordinary line a distance of 6 or 7 miles a day, returning the same evening with the empty truck. The length of the logs extracted varies from 12 to 24 feet. The length varies inversely as the girth, so that a long log is not heavier than a short one; as a rule the converse is usually the case; some logs, 50 feet in length, have been carried on a pair of trucks over the straight and level portions of the line.

Anamalai timber tramway.—It was intended to use bullocks as the motive power at the time that this tramway was purchased, and they are now used to haul the laden trucks. One, two or three pairs of bullocks are used, according to the size of the logs. In 1889-90 elephants were used instead of bullocks for hauling large logs up the tramway. An elephant was found to do as much work as nine bullocks, and can draw heavy logs which cannot be taken out by bullocks. One elephant took out a log containing 108 cubic feet solid on a pair of bogie trucks in one day over a distance of 3½ miles. The average daily load was 58 cubic feet solid for a whole month, while a fair load for one day was 75 cubic feet solid. The elephants were used twenty days in the month.

The elephants could not, however, be spared from their other work of dragging the logs to the tramway from the places where

the trees were felled, so that bullocks had again to be employed as the motive power.

The result of the experiment of using elephants as a motive power shows that the cost of extraction of logs along the tramway, as long as the steep gradients on the road exist, is much decreased by their use.

In 1889-90 the average cost of extraction of timber by elephants was 2·84 pies per cubic foot solid per mile, while that extracted by bullocks cost 4·4 pies per cubic foot solid per mile. It should also be noted that the elephants could haul the largest logs, while small or medium-sized logs only could be extracted through the agency of bullocks.

The elephants did not do (so far as could be ascertained) any material damage by walking on the rails and sleepers, but since the brakes were unreliable, there was considerable danger of the loaded trucks on the steeper gradients running on to, and so damaging, the elephants.

The above cost of extraction is deduced from the volume of timber removed per mensem, and the monthly cost of keeping the elephants or bullocks, and does not include the initial cost of the animals used.

Nellore District fuel tramways.—On these tramways, sugar-cane wagons, type J (fig. 49, page 75), are used for the transport of the fuel, and the wagons are drawn by coolies, two coolies being allowed to each truck. The trucks carry from ¾ to 1 ton of fuel. They are 3 feet 9 inches high, exclusive of the wheels, and 5 feet long. Bullocks were first tried, but were found to be unsuitable. The number of trips made by the coolies in a day depends entirely upon the distance. If the lead is one mile, one set of coolies can make four trips a day. The wagons are not provided with brakes, nor are they required.

Changa Manga fuel tramway.—Bullock power is the tractive force employed at Changa Manga. One pair of bullocks haul three trucks, one of the old type (fig. 55, page 81) and two of the new type (fig. 56, page 81). The weight of these three trucks is 1,752 lbs. and that of the fue in them 8,364 lbs., so that

the total weight drawn by the two bullocks is 10,116 lbs., or nearly 4½ tons. The line is practically level and the steepest up gradient is only about 1 in 100. The number of trips made in one day depends upon the distance to be traversed, the time of year, and the weather. When the distance was from 1 to 1½ miles, five trips were made on an average during the longer days and three during the shorter ones. When the distance to be traversed was 3 miles or more, two trips are made when the days are long and one when they are short.

SECTION VI.—DRY AND WET TIMBER SLIDES.

§ 73. Timber slides can only be used for the extraction of timber, either in the log or converted into sleepers and scantlings from higher to lower elevations in hill forests.

Timber in the log is usually taken down dry slides, while scantlings are more commonly taken down wet slides.

In the case of dry slides the logs move down in virtue of their own weight only, whereas in wet slides, water is used as an additional motive power.

Dry slides fall naturally into two well-marked classes—

(1) Earth slides. | (2) Wooden slides.

In the former class the trough down which the logs slide is not lined in any way. In the latter the trough is lined with wood. The wooden lining has the effect of materially decreasing the friction between the descending logs and the sides and bottom of the trough.

§ 74. Earth slides.—An earth slide is simply a natural depression or hollow, improved by artificial means, such as the removal of trees and boulders, and the blasting of projecting pieces of rock, so that logs can be worked down it end-wise by means of levers. Where no natural depression exists in a suitable position, an entirely artificial depression may be constructed to serve the same purpose.

Earth slides may be taken across the slopes of hills where the ground is suitable.

With regard to the earth slides in the Bahshahr Forest Division, Mr. Minniken, Deputy Conservator of Forests, writes—"In selecting the ground for an earth slide, the preference, if there be any, is given to ground with deep, hard soil or to nullahs and depressions with rubbly and stony bottoms."

Width.—"The width of earth slides varies from 5 to 25 feet with the natural slope of the ground over which they are made; being concave there is seldom any necessity for erecting sides. But as the logs are moved from side to side in a zig-zag line and slide a short distance each time they roll over, they sometimes leave the slide at certain points, rolling into *débris* or the forest from which it is not easy to extricate them. Posts or rough walls are erected at those points at which the logs are liable to leave the slide; or the slide itself is deepened at the points where the logs get an impetus and are likely to leave it."

Curves.—"Generally speaking, the slides are straight, but when natural curves or bends of short lengths occur, at not too frequent intervals, they are an advantage. There is seldom sufficient room to set out regular curves, and they are of little consequence in any case, as the logs do not move quickly down the slide for long distances, but are moved slowly from side to side of the slide for short distances at a time."

Gradient.—"The gradient of an earth slide depends upon that of the natural slopes of the hill sides to a very great degree. It varies between 20 and 60 degrees."

"So long as the slope does not exceed from 20 to 25 degrees, logs can be taken down without danger of their getting out of control, except, perhaps, in wet weather; consequently, so long as the slopes do not exceed 25 degrees no special steps need be taken to check the velocity with which the logs move downwards. Where the gradient exceeds this amount, walls are erected across the slide at intervals, in order to stop the rapidity with which the logs descend, and to bring them to a standstill. These walls are called *check walls.*"

"The strength of check walls, as well as the distance between them, depends upon the nature of the ground, the

resistance offered by the soil, the gradients and the size of the logs brought down."

The following table shows the distances between the check walls at different gradients under ordinary circumstances:—

Gradient, in degrees.	Distance between check walls, measured along the surface of the ground, in feet.
30	300 to 500
35	200
40	150
50	100
60	50

The construction of the check walls is described by Colonel Bailey as follows,[1] see figures 70 and 71, page 113:—

"At a selected point on the earth slide, a terrace, from 15 feet to 30 feet wide, is cut out of the hill-side. On its outer edge a row of deodar logs (A, A, A, Fig. 70.) of some 18 feet in length is planted perpendicularly to the direction of the slide, the logs being from 6 feet to 8 feet apart and having about one-third of their length buried in the ground. Behind them is erected a roughly-constructed wood and stone wall from 10 feet to 20 feet wide at the top and about 6 feet to 10 feet high on the inner side. The wall rests on a foundation of solid earth cut out to receive it. Sometimes the outer face of the wall is supported by a second row of logs, the spaces between them being filled up with rough poles and other pieces of wood, so as to hold the stones firmly and prevent their being displaced by the shock of the falling logs."

[1] "The Indian Forester," Volume XII, pages 136 and 317.

FIG. 70.

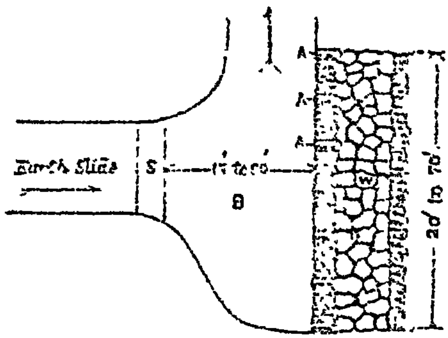


FIG. 71.

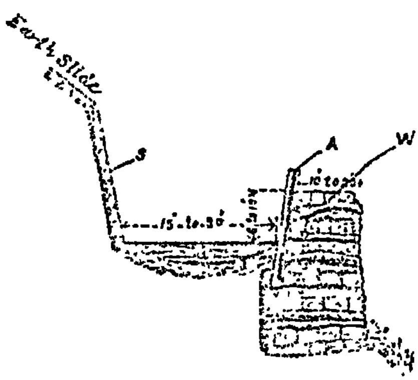


Figure 70 is the plan of a check wall as constructed in connection with the earth slides in Bahshahr, Punjab Himalaya : A, A, A *are posts between which brushwood is intertwined and against which the logs strike ;* B *is the bed of soft earth or brushwood on which the logs pitch ;* W *is the stone wall which supports the line of poles and forms the check wall proper ;* S *is the steep sloping surface leading from the slide proper to the bed on to which the logs fall.*

Figure 71 is the cross-section through a check wall of which figure 70 is the plan. (Reduced from figures in the "The Indian Forester" *for May 1889.)*

"If the floor of the terrace be hard, it is usually dug out to a depth of some 4 or 5 feet, and the hollow thus formed (B figure 70) is filled with loose soil or brushwood, so as to check the fall of the logs and stop them altogether, or at any rate to moderate the force with which they strike the wall. The logs are then moved by means of levers to the head of the next section of the earth slide, which is usually at one end of the check wall, but more rarely at its centre, an opening being left for the passage of the timber."

"On very steep slopes, where check walls are required at short intervals, it is not always possible to find places where good foundations can be obtained. In such cases a partial check is afforded by simply driving a row of iron jumpers or crowbars into the ground so as to support a line of logs laid horizontally above them. Such obstacles are much shorter than an ordinary check wall, and must obviously be placed nearer together than would be necessary could ordinary check walls be employed. Check walls in the Bahshahr Division are said to cost about R2 per 100 cubic feet of walling."

"Where the nature of the ground is such that there is a danger of the logs leaving the slide, check walls may be placed obliquely to the direction of the earth slide at those places, in order to prevent the descending logs from leaving the slide."

"The earth slides in the Bahsháhr Division are said to cost R12 per 1,000 superficial feet of ground prepared."

Mr. Minniken continues to say that "among the many contrivances connected with the transport of timber down earth slides, check walls require the most attention. On slopes which an inexperienced eye would condemn as impracticable for sliding timber, if check walls are judiciously placed and properly constructed, logs of the largest dimensions can be moved down with great regularity and without risk of breakage."

Manner of sliding down the logs.—"The logs are not allowed to move down any dry earth slides more than a few feet at a time; for, if they were, the force with which they would impinge against the check walls would be sufficient to injure them

very considerably; and in the usual distances between the check walls the logs would gain such a velocity that no ordinary wall could withstand such repeated concussions for long. The logs are therefore moved along in batches of a hundred or more by gangs of coolies, who are each supplied with a wooden lever six feet long, with the help of which they move the logs down and soon become very expert at this work."

Size of logs transported.—"The logs which are taken down the dry earth slides vary from 5 to 17 feet in girth, from 10 to 25 feet in length, and from one-fifth of a ton to 3 tons in weight. They are put into the slide lengthways, and are kept as far as possible in this position, until they reach the place where they are to be launched into a stream suitable for floating, or join a rolling road or a wooden slide."

Percentage of breakages.—"An account has been kept in the Bashahr Division of the actual breakages of logs taken down dry earth and dry wooden slides for the last fifteen years, and this record shows that only one log in every 140 is broken in its passage down the slides, and that the number of logs injured in transport only amounts to 5 per cent."

Damage done to dry earth slides.—"In consequence of the majority of the dry earth slides having been made in natural depressions, they are peculiarly liable to damage from falling rocks, snowslips, avalanches and water, consequently when it is proposed to exploit a forest by the agency of dry earth slides, the check walls should not be built until after the season for the occurrence of avalanches is past. The cost of repairing the damage done to an earth slide and maintaining it in working order during the first year averages, for all slides, 20 to 30 per cent. of the initial outlay."

§ 75. EUROPEAN EARTH SLIDES.—In Europe, earth slides consist of a groove 3 to 5 feet wide cut in the earth and sometimes even in the rock. The edges of the slides are protected by one or two long poles placed one above the other. The lower ends of these stems overlap the upper ends of those next below them in order to prevent a descending log from striking against a

projecting surface and being thrown out of the slide. Fairly sharp curves are allowed on these slides. The outer edge of the slide along curves is made higher, and backed if necessary by an embankment of earth or stone in order to strengthen the structure. Poles fastened obliquely to the direction of the slide and sloping towards the inner edge of the curve, are placed across its bed on the curves to facilitate the passage of the descending logs round them.

The girth of the logs taken down these slides is very much less than that of the logs taken down earth slides in India.

The gradient of such slides, when the ground is frozen and covered with snow, should not be more than from 20 to 25 degrees.

§ 76. DRY WOODEN SLIDES.—This term is applied to trough-shaped slides made of round logs or planks roughly fitted together, in contradistinction to those wooden slides which are made of planks or scantlings accurately fitted together so as to hold water. Dry wooden slides are constructed to take logs across hill slopes; or in localities where the ground is very rocky, and it would be both difficult and expensive to form an earth slide.

A wooden slide may be constructed of logs approximately of the same size, laid in a cup-shaped depression prepared to receive them, or else of logs of different sizes fixed to wooden supports placed at intervals on the ground or the prepared track.

Wooden slides were constructed in the Punjab Himalaya for the extraction of very long logs which were at that time in demand for beams used in the construction of terraced roofs; but since rolled iron beams and old rails have come into general use in building construction, the demand for very long wooden beams of a large girth has ceased.

The Bakani slide (see page 119, *et seq.*), which was constructed in 1883-85 in the Bohar-Padri forests of the Chamba State, is an example of the first kind, while the Kilba slide (see page 122, *et seq.*) in the Bahshahr State may be taken as a type of the second

class. Dry wooden slides may be made of any required length. In the North-Western Himalaya, however, the mountain sides are so precipitous, and the slopes which are suitable for the construction of timber slides are so frequently interrupted by scarps and precipitous ground, over which it would be impracticable to construct a wooden slide, that, as a rule, only short dry wooden slides can be made, and the character of the means of transport employed varies from place to place with the nature of the ground passed over. In Chamba as a rule, the forests from which the timber is exploited are so scattered and so small that the cheapest method of extraction, now that the export of logs has been discontinued, is to carry the sleepers or other converted pieces, by men, along sleeper paths to the nearest floating stream.

Gradients.—Experience has shown that the gradient of dry wooden slides should not be made uniform, but that it is better to change the gradient frequently. Portions with steep gradients should be succeeded by lengths with a low gradient so as to reduce the velocity with which the logs travel. The lengths of the portions of the slides with low gradients depend upon the lengths and gradients of the steep portions above them, and should be such that the logs are moving quite slowly by the time that they have reached the top of the next steep portion of the slide.

Where the gradients are very steep, the velocity with which the logs move can be lessened by throwing earth or sand on the slide, or else by cutting notches in the logs which form the base of the slide itself. Both these expedients increase the force of friction, and consequently decrease the velocity of the descending logs.

Where the gradient, in consequence of the nature of the ground surface, is too low to allow of the logs moving down in virtue of their own weight, arrangements should be made for leading water on to the slide. The water will render the slide more slippery, and will facilitate the downward passage of the logs.

The best gradient for dry wooden slides constructed for the transport of large logs varies between 15 and 25 degrees. If the gradient is as much as 30 degrees, special precautions must be taken to prevent the logs from moving down too rapidly, and also to bring them to rest at the lower end of the slide. If the velocity with which the logs reach the bottom of the slide is considerable, the lower end of the slide itself should be made quite level, or even inclined slightly upwards in order to bring the logs to rest when they arrive at the bottom of the slide.

If it is not practicable to give the lower end of the slide a level or slight up-gradient, a depression filled with brushwood should be constructed just beyond the end of the slide so as to break the fall of the descending logs, which will shoot end-on on to the place prepared to receive them.

§ 77. CONSTRUCTION OF DRY WOODEN SLIDES.—When a dry wooden slide is to be made of logs approximately of the same size, after the slide has been aligned and the trough-shaped depression for the reception of the logs formed, the only thing that remains to be done is to place the logs in position. The logs which are to be transported may be used in the construction of the slide stself, as was done at Bakani (see fig. 72, page 119), and in this case, after all the logs have been transported, the slide itself is broken up, beginning at the upper end, and the logs thus obtained slid down the remaining portion of the slide. This procedure is very strongly recommended; as, if followed, the initial cost of the slide will be very materially decreased, and experience has shown that the logs are practically not damaged by the passage of the other logs over them.

FIG. 72.

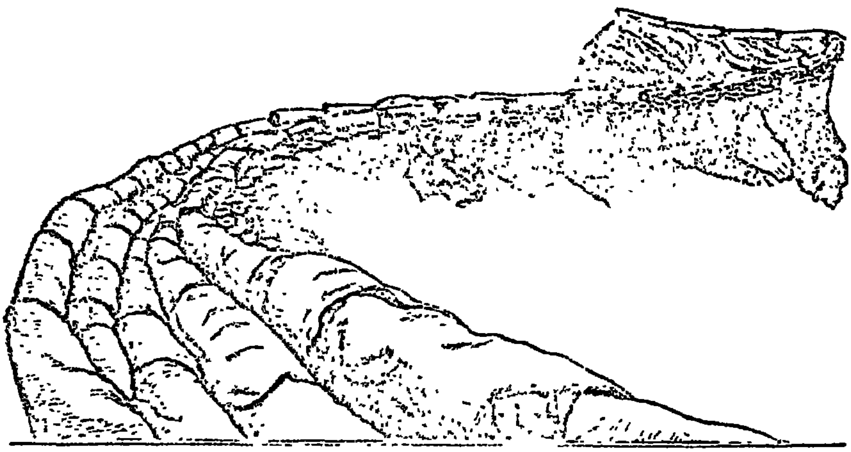


Figure 72 shows the construction of the Bakani timber slide (from a photograph).

The logs forming the slide are made to break joint with one another. The construction of the slide itself is very simple and rough, and the success of the slide will depend almost entirely upon the care and skill with which it has been aligned in the first instance, and only in a secondary degree upon its actual construction.

When logs of different sizes are employed in the construction of the slide, the larger logs form the sides and the smaller ones the bottom. The logs are fastened by trenails to wooden supports, laid on the surface of the ground or on piers, built up so as to give the slide the required gradient, and the individual logs are halved on to each other. In this case the slide is not constructed of the logs which are to be transported.

Figures 73 and 74, page 123, show the construction of a slide made of logs of different sizes.

§ 78. INDIAN DRY WOODEN SLIDES.—"The *Bakani slide*, which was constructed for the special purpose of transporting long logs of large dimensions from the Chamba forests to the banks of the Ravi,

[1] Report on the Bakani Slide, 1886, by Mr. J. C. McDonell, then Deputy Conservator of Forests.

was commenced in May 1883 and completed in October 1885. The total length was 12,539 feet and the difference in elevation between the highest and lowest points of the slide was 1,650 feet, which gives an average gradient of 1 in $7\frac{1}{2}$ or about $7^{\circ}\cdot35$.

In aligning the slide in the first instance, the gradient was made as uniform as the physical difficulties of the ground would allow of, as it was intended to drag the logs down the slide. When the slide was opened to traffic it was found that it would have been better if, instead of preserving a more or less uniform gradient throughout, the slide had been constructed with steeper gradients alternating with level or nearly level portions. In this way logs might have been dragged along the level portions until they reached the tops of the inclines, which should have been steep enough to allow of the logs brought on them to slide down of their own accord. As the slide was actually constructed it was found necessary to set the logs in motion by having them pulled for some distance after each stoppage by gangs of coolies walking and running along the tops of the logs forming the sides of the slide. Several men were killed by slipping off the sides and falling in front of the logs as they were moving down. The maximum gradient on the slide was 1 in 5 or about 11·18 degrees, while the lowest gradient was 1 in 20 or 2·52 degrees. The slide crossed the stream once, in order to avoid some difficult ground and a large landslip. The track on which the slide was laid was 10 feet wide. The slide itself was constructed of from four to six logs, laid side by side, according to their size, so as to form a trough-shaped depression, the length of the logs used was from 15 to 20 feet on an average. The logs were placed end to end and were embedded in boulder ballast. When the slide was taken across a depression it was supported on crib-work piers, 8 feet long and 12 feet wide at the top. Nearly 4,000 logs were used in the construction of the slide. Originally it was intended to drag the logs down the slide, but it was found that when once set in motion they would move unaided down the slide where the gradient was 1 in $7\frac{1}{2}$ provided the slide was kept wet. The speed of the logs increased with the amount of water admitted. Logs up to 6 feet in diameter could be taken down the Bakani slide.

The longest log taken down the slide was 48 feet in length, while the largest log was 27 feet long and $14\frac{3}{4}$ feet in girth, with a volume of 367 cubic feet.

After all the logs had been worked out of the forest, the logs of which the slide itself was made were worked down it, beginning at the upper end, as it was found that the logs of which the slide were made were not damaged by the passage of the other logs over them."

§ 79. FINANCIAL ASPECT OF THE SLIDE.[1]—" The primary cost of construction of the slide was R31,259 for 2·35 miles, or about R13,300 a mile.

[1] Mr. A. L. McIntire, Deputy Conservator of Forests, Punjab.

The actual expenditure on the extraction of the timber is as follows:—

	R
Construction of main slide	31,259
Repairs to main slide	4,972
Construction of, and repairs to, auxiliary slides	26,540
Working down to slide and launching 569,000 cubic feet of logs	67,180

That is 3·83 annas a cubic foot of timber cut, or 4·06 annas a cubic foot launched. Eleven thousand nine hundred and ninety-one logs contained 513,165 cubic feet, or on an average 42·8 cubic feet per log.

It was estimated that 10 per cent. of the timber launched would be lost in transit, and that the cost of collecting the remainder in sale depôts would be 2 annas 9 pies a cubic foot, and that the average sale price would be 12 annas per cubic foot. At this rate the net profits would have been $\frac{9}{10}\times569{,}000\times(12-2{\cdot}75-\frac{10}{9}\times3{\cdot}83)$ annas = about R1,58,075, or say R1,58,000. Actually although the launching began in 1886, and was finished in 1890, up to the end of January 1895 only 8,811 logs containing 262,541 cubic feet, or an average of 29·8 cubic feet each, were received in sale depôts and identified as Bakani timber, of the remainder a part was still in transit, and some of the smaller logs had been received in sale depôts without identification, or had, after the disappearance of their marks, been appropriated by the Kashmir State. In any case it seems most improbable that future receipts will raise the average sale depôt contents of each log launched, *viz.* 29·8 cubic feet, materially, and even if the number of logs actually lost turns out to be so small as to be negligible, the loss from shrinkage, breaking of ends, knocking off of sapwood, etc., in transit cannot be much less than 42·8—29·8 cubic feet per log or 30 per cent. on the whole of the timber launched. Comparisons carried out for about 2,000 logs show that in individual cases of logs, which reached sale depôts in what is for the Ravi a short time, *viz.* two to three years, and in good condition, the loss from shrinkage only is about 20 per cent.; but this figure is evidently too low to be accepted as an average for all logs launched.

Taking the loss in transit from all causes at 30 per cent. of the actual launchings, the cost of launching the Bakani timber actually received at the sale depôts is raised from 4·06 to 5·58 annas a cubic foot. For collecting in the sale depôts a further allowance of 2 annas a cubic foot must be made, bringing the total cost of delivery per cubic foot to 7·58 annas.

Of the 513,165 cubic feet launched from the slide, only $\frac{7}{10}$th, or, say, 360,000 cubic feet can be expected to reach the sale depôts. Of this amount 187,927 cubic feet have been actually sold for R1,42,930 or 12·17 annas per cubic foot. But owing to the depreciation of long logs, and the loss in transit, not more than 10 annas can be expected for the balance of 172,073 cubic feet, or R1,07,545. Hence the total sale proceeds are not likely to exceed R2,50,500, whilst the expenditure on 360,000 cubic feet at 7 annas 8 pies will be R1,75,500, leaving a profit of R75,000. This is the maximum profit there is any probability of obtaining.

If, instead of logs, scantlings such as railway sleepers had been cut and launched, without allowing for possible savings through avoiding breakages which took place in working logs down the slide, it is certain that for every 100 cubic feet of log, at least 95 cubic feet of scantlings would have been delivered in the sale depôt. The outlay would not have exceeded 4·5 annas, and the selling price for the last ten years has been 11·72 annas per cubic foot, hence the profit would have been at least $\frac{55}{100} \times 513{,}165 \times (11{\cdot}72 - 4{\cdot}5)$ annas or about R1,27,000.

It must be added that the slide was made with the object of delivering long logs in sale depôts. Such logs then commanded high prices, which, owing to the introduction of rolled iron beams, old rails, etc., into the market, are no longer attainable. But for this change in the market, the profits would have been nearly or quite equal to the original estimate, notwithstanding the very heavy loss in transit."

§ 80. THE KILBA SLIDE was made in two sections. The upper one is 400 feet long, and has a gradient of about 22°; the lower one being also 400 feet long with a gradient of from 25° to 27°. The two sections of the slide were connected by an earth slide 50 feet long.

The following description of the method of construction of the slide is taken from a paper written by Colonel F. Bailey, R.E., in the "*Indian Forester*" for April 1889, volume 15, page 137:—

"The slide in section is composed of 5 logs or tree tops (A. A., b. b. c., figure 73, page 123) so disposed as to form a roughly made trough. The two larger pieces (A.A.) lying at the outside are about 5½ feet in girth, the inner poles being smaller. The ends of these timbers rest on a roughly made round sleeper (S.), to which they are pinned down with spikes of oak-wood (K, K.). The tendency of the timbers to slip forward when the slide is in use is further checked by their being notched on to the sleepers (*see* figure 74, page 123). The line of timbers is prolonged by others of similar dimensions attached to them by a rough scarf joint (*see* figure 74, page 123). This is not always done. Sometimes the timbers are simply placed end to end, a stout picket being driven into the ground between them, so as to prevent the upper one from working forward. The sleepers rest on a rough bed of stones and wood, filling up the inequalities of the ground, and built up to the required level. Figures 73 and 74 are reduced from drawings in the "*Indian Forester*."

FIG. 73.

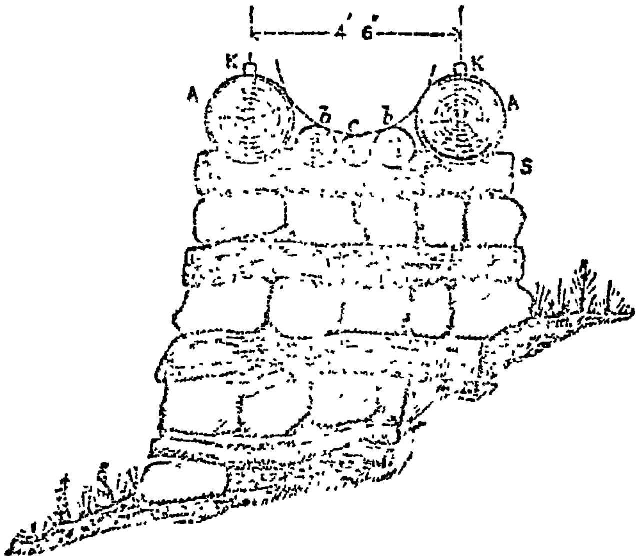


FIG. 74.

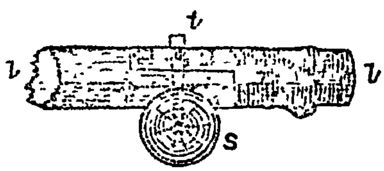


Figure 73 is a cross-section of the Kilba dry timber slide. A, A, b, b, c *are the 5 logs or poles of which the slide is made up.* S *is the round sleeper on which the logs rest and to which they are pinned with oak trenails* K, K. *The slide is shown resting on a rough support made of poles and stones. The logs of which the slide is made up are notched on to the round logs on which they rest. (Scale 4 feet = 1 inch.)*

Figure 74 shows in detail how the logs are joined over the sleeper (support S. l, l *are the logs of which the trough is made and* t *the trenail (*K *of fig. 58) fastening the logs on the support* S. *(Scale 4 ft. = 1 inch.)*

§ 81. EUROPEAN EXAMPLES.[1]—Dry wooden slides, combined with a system of portable and permanent tramways, are used in the Sihlwald forests belonging to the town of Zürich in Switzerland for the extraction of timber and firewood. The forest is situated chiefly on the left bank of the Sihl river at elevations varying from 1,574 to 2,995 feet (480 to 913 metres). The slopes vary from gentleto very steep; 36 per cent. of the total outturn on an average is timber, the rest being firewood.

The gradients of the slides vary from 15 to 25 per cent. (8½ to 14 degrees). Their construction is of the simplest kind. The general plan of those for transporting logs consists of a concave trough formed by placing 4 or 5 logs side by side resting on a block of wood in which an obtuse V-shaped notch has been cut (see fig. 75).

FIG. 75.

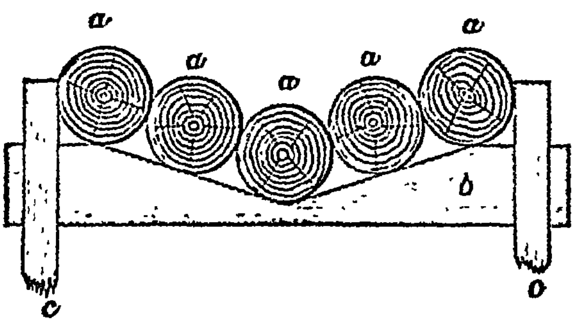


Figure 75 is a cross-section of a dry timber slide in the Sihlwald, near Zürich, Switzerland; a, a *are the poles of which the slide is made :* b *is one of the notched blocks on which the poles rest ;* c, c *are the posts which are driven into the ground and keep the logs from moving laterally. (Drawn by Mr. J. Copeland).*

The wedges are kept in position by stakes driven in near either end of the block. This block may rest directly on the ground or on several layers of logs placed crosswise on each other, or they may be supported on trestle-work built to any required height in order to maintain the proper gradient. The

[1] Journal of a tour made in the Continental Forests of Europe (1893), by Mr. J. Copeland, Deputy Conservator of Forests, and notes made by the author in the Sihlwald in 1898.

trestle-work supports are, as a rule, only used where deep streams have to be crossed. The slides are roughly put together but are very effective. One slide at Sihlbrugg is 984 feet long (300 metres), has been in use for eight years and has brought down many large logs. An aneroid barometer showed that the difference in elevation of the top and bottom of the slide was 400 feet, which gives a mean gradient for the slide of 22° 6′ The extreme end of the slide was given a slight upward curve so as to pitch the logs out of the slide on to a soft bank of earth some 65 feet (20 metres) below. Where the gradient is steep the velocity of the logs is checked by throwing earth into the slide.

The poles of which this slide is constructed vary from 4 to 9 inches in diameter, and some of them are slightly notched on to the logs or blocks of wood which support them. Where the slide is supported on trestle-work, the trestle supports are placed 6 feet apart. Slabs of wood 1½ inches thick and 6 inches wide take the place of the side poles on some of the slides down which logs are worked.

The poles or slabs of wood of which the slides are constructed are the same length or do not break joint. They are joined over the supports. The direction of the slide is practically straight, but there are some very slight curves on it. Experience shows that the descending logs are very apt to leave the slide at the curves, and the sides of the slides at these portions are heightened so as to prevent this. The height of the supports on which the trough rests are regulated to make the gradient practically uniform. The gradient of the top of this slide is 25° (45·6 in 100), while the gradient of the lower portion, excluding the extreme end which is curved slightly upwards, is 17° 20′ (31·2 in 100). The middle portion of the slide has a gradient of 22° (40·4 in 100).

Firewood in billets can also be sent down these slides, but where the slides are not intended for the transport of logs they are made very much slighter. They then usually consist of a trough made with slabs and useless planks (see fig. 76, page 126). The bottom planks are nailed to blocks similar in construction

to those used for the timber slides, while the side pieces are nailed to upright posts, as shown in figure 76.

FIG. 76.

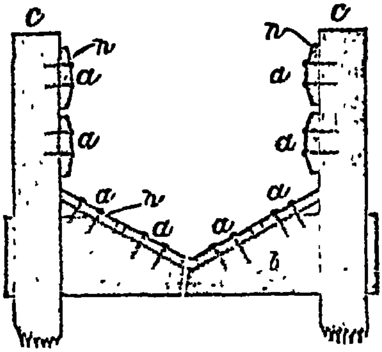


Figure 76 is a cross-section of a dry fuel slide in the Sihlwald, near Zürich, Switzerland; a, a, a *are the planks which form the slide seen in cross-section;* b *is one of the notched blocks on which the slide rests;* c, c *are the posts which keep the blocks from slipping, and to which the planks, which make the side of the slides, are nailed;* n, n *are the nails. (Drawn by Mr. J. Copeland.)*

The blocks to which the planks are nailed either rest on the tops of posts, or are supported by battens nailed to them. The portion of the shoot or slide, where it crosses a road, is made detachable and, when not in use, is lifted off its supports and placed on one side, so as not to interfere with the traffic along the roads. The structure looks fragile and rickety, but answers its purpose very well. Care is taken to avoid anything in the way of projections to the downward course of the billets, and for that reason the upper edge of a plank is laid, if anything, a little lower than the lower edge of the one next above. A peculiar feature of the firewood shoots is the spring board at the bottom. The billets strike against this and are thrown a distance of 164 feet (50 metres) to the collecting place. The laying of the platform at the proper angle is a matter of great nicety. The spring board is faced with iron plates about three-fourths of an inch (2 centimetres) thick and 5 inches (15 centimetres) wide.

In the case of a portable fuel slide seen working, the average down gradient of the slide was 18° 10′ (32·8 in 100) and the

platform at the bottom of the slde was laid sloping upwards at an angle of 14° 20′ (25·5 in 100) to a horizonal plane.

Figures 77 and 78[1] show the way in which this platform is constructed and fixed in position.

FIG. 77.

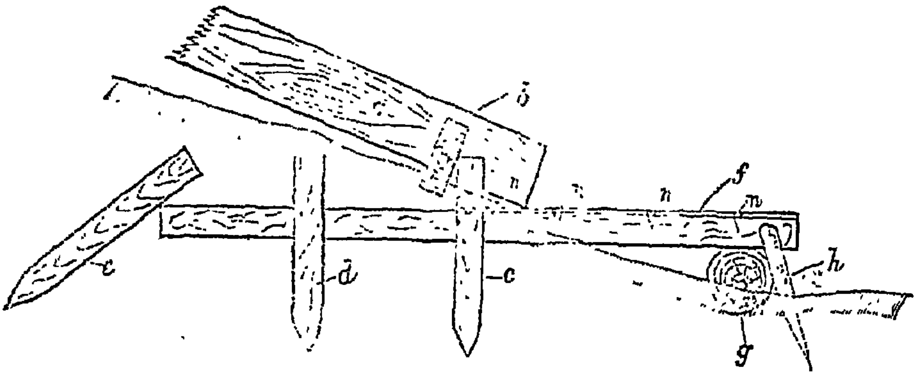


FIG. 78.

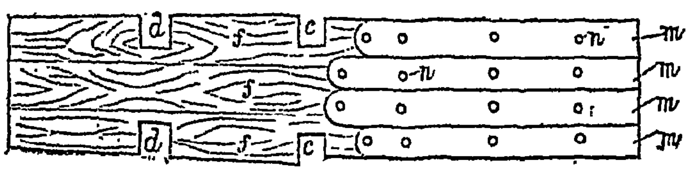


Figure 77 is a side elevation of the lower end of a portable dry fuel slide with a spring board fixed in position: a *is one of the planks of which the slide is constructed;* b *is the end of one of the wooden blocks to which the planks are nailed;* c *is one of the stout pegs driven into the ground to keep the slide in position;* c *and* d *are pegs placed in the notches* (c, d, *fig. 78*), *which keep the spring board from moving;* e *is another stout peg driven in against the end of the spring board to prevent its slipping backwards;* f *is one of the scantlings of which the spring board is made up—there are 3 of them* (*see* f, f, f, *fig. 78*); g *is the log kept in position by two stout pegs* (*only one is seen*) *driven into the ground in front of it, on which the free end of the spring board rests;* n, n, n *are the screws which fasten the thin sheets of iron* m, m, m, m (*fig. 78*) *to the surface of the spring board.* (*Scale* = $\frac{1}{20}$.)

Figure 78 is a plan of the spring board; the letters used are the same as those used in the description of fig. 77. (*Scale* = $\frac{1}{20}$.)

[1] Copied from Holz-transport in dem Stadtwaldungen von Zürich gezeichnet von C. Hartmann, Forst Assistant, 1880.

§ 82. In the Sihlwald, portable fuel slides 200 or 300 feet in length have now to a large extent superseded the fixed ones. The sections of these portable slides are made of two planks nailed on to two blocks of wood so as to form a V-shaped trough. The planks are about 16 feet (5 metres) long, 12 inches (30 centimetres) wide and 1¼ inches (3 centimetres) thick. The blocks of wood are placed at a distance of 11 inches (28 centimetres) from the ends of the planks. Each plank is fastened by two nails to each support. These blocks of wood are notched so as to afford bearing surfaces to the planks (see fig. 76, page 126). The blocks of wood are 22 inches (55 centimetres) long, 7 inches (18 centimetres) deep and 3 inches (7½ centimetres) thick.

When a slide is constructed of these portable sections, poles about 11 inches in girth are driven firmly into the ground at suitable intervals and the blocks of wood to which the planks forming the sides of the slide are nailed, rest against these poles. Intermediate supports are added at the mid-lengths of the sections to stiffen and strengthen the slide. Slabs of trees which are first barked are nailed on to the planks where they are worn by the passage of the fuel down them. The upper end of the slide is placed about 28 inches above the surface of the ground, so as to allow of the billets of wood being placed directly into it. The slide is kept well greased, and is absolutely straight. The gradient is practically uniform, the upper portion being slightly steeper than the lower portion. The average gradient of one seen in use was 18°·10′ (32·8 in 100), while that of the top portion of it was 20° (36·4 in 100). The lower end of the slide abuts on a spring board faced with steel plates (see § 81, page 125) and the descending billets impinge on this board and are thrown from 50 to 70 feet beyond the lower end of the slide itself.

The lowest part of slide wears out the quickest, and it is here that the barked slabs of trees are chiefly nailed on. The poles upon which the sections of the slide rest are tied together with strips of beech bark to prevent their spreading. These poles are driven firmly into the ground, and if they work loose, stout pegs are driven into the ground by their sides until they become quite firm again.

§ 88. WET WOODEN SLIDES.—In this class of slide, water is used as a motive force, in addition to the force of gravity. The slide itself is constructed of sawn timber carefully fitted together the joints being caulked with moss or some fibre to render them water-tight. These slides are used for the transport of converted timber only. The slide may be open or covered in. So long as the gradient is less than 25 degrees the slide may be an open one; if, however, the gradient of the slide exceeds this amount, it should be covered in, so as to prevent the converted timber from leaving the slide.

The *gradients* permissible on an uncovered slide vary between 5 and 25 degrees, the best gradient being about 15 degrees. If the slide is covered in, the gradient may be as much as 45 degrees. On low gradients a much greater supply of water is required than on steep ones. On very steep gradients the slide practically becomes a dry slide, into which a little water is admitted in order to prevent the slide being set on fire by friction.

The changes in the gradient of the slide should be made very gradually, especially those from a lower to a steeper one; for if sudden changes in the gradient are made, the descending timber will be thrown out of the slide.

Whenever possible, the gradients should be lower on the curved than on the straight portions of the slide.

The gradients should be small near the lower end of the slide, so that the descending scantlings may just reach the lower end.

If the gradient is fairly uniform throughout, the direction of the slide itself generally straight, and the necessary curves made as gentle as possible, the working of the slide will be much more satisfactory than will be the case if very little attention has been paid to the gradients and the construction of the curves on the slide.

In Europe, on timber slides where the gradients are too steep and the descending timber travels with a dangerous velocity, a simple contrivance for reducing its speed is used. This

consists of hanging above the slide a pole or beam, the lower end of which lies in the slide. The pole works on a simple hinge and the end lying in the slide may be weighted to any extent required. The descending timber must raise the hinged pole in its passage down the slide, and in so doing, the velocity with which it is moving is decreased. The brake lies obliquely to the course of the descending timber and consequently does not damage it. On very steep gradients these brakes do not work very satisfactorily.

Size of the trough.—The trough in which the converted timber travels should be made slightly larger than the size of the largest scantling which is to pass down it. If the slide is made much larger than this, the scantlings will have too much play and will continually knock against the sides of the trough and thus loosen the joints between the sides and the bottom of the slide, causing it to leak badly, especially round the curves.

The trough should be wider at the curves than on the straight portions, in order to allow the descending timber to move easily round them. The bottom of the trough is for the most part level on a cross-section, but round curves it has been found advisable to slope the base of the trough inwards. If this is done, the forward end of the descending scantling is drawn continually towards the inner edge of the curve, since the water is deepest at that part of the trough and is thus prevented from striking violently against the outer side of the trough.

Curves.—Experience in India has shown that it is extremely difficult to work a wet slide that has a great number of sharp curves in it satisfactorily, more especially if the gradient is at the same time steep. The fewer and gentler the curves are the easier, more smoothly and less expensively can the slide be worked. If there are no curves the working of the slide will be very simple, and the repairs comparatively slight. Wet slides always leak at the curved portions first, for the reasons noted above. The gentler the curve the smaller the force with which the sleepers will tend to impinge against the outer side of the

trough. The actual radius of the sharpest curve, which is permissible, depends upon the length of the scantling to be transported.

Construction of a wet slide.—In India, wooden wet slides are made of three planks, one of which forms the bottom and the other two the sides of the trough. The planks are usually about 12 feet long and from 2 to 5 inches thick. The width of the planks varies with the size of the trough required. The planks forming the base of the trough should be halved, as shown in figure 79, so that the upper plank fits over the lower one, and no project-

FIG. 79.

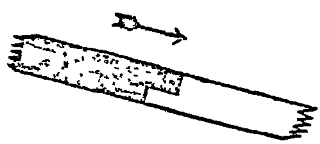


Figure 79 shows the method of joining the planks which form the bottom of the slide. The arrow shows the direction in which the sleepers move. (Scale = $\frac{1}{24}$.)

ing surfaces oppose the sleeper or scantling during its passage down the slide. The side pieces may be similarly joined, or else as shown in figure 80.

FIG. 80.

Figure 80 shows how the planks which formed the side of the Deota wet slide are joined. (Scale 2 feet = 1 inch.)

The joints may be all made over one support, or, what is better, the joint between the side planks may be made on one support and that between the planks forming the bottom of the slide over the next one.

FIG. 81.

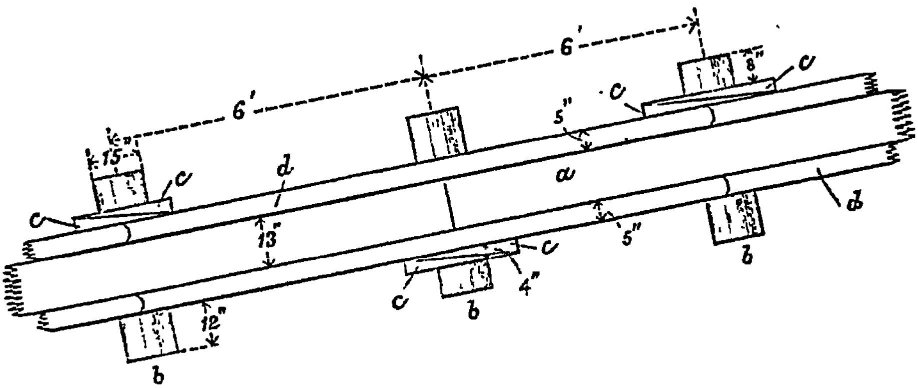


FIG. 82.

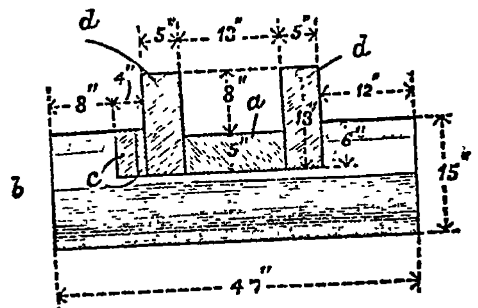


Figure 81 is plan of a portion of the Deota wet slide to show how it is supported upon blocks and how the side and bottom pieces are joined; a *is the bottom;* d, d *the sides of the slide;* b, b, b *are the blocks by which it is supported at intervals of 6 feet;* c, c *are the wedges which keep the sides and bottom of the slide together. (Scale 4 feet = 1 inch.)*

Figure 82 is a cross-section of the Deota wet slide; a *is the bottom of the trough;* d, d *the sides;* c, c *the wedges which keep the bottom and side together;* b *is the block in which the trough is fixed. (Scale 2 feet = 1 inch.)*

The trough itself is supported on rough wooden blocks wherever the planks forming the sides or the bottom of the trough are joined. A notch is cut in the block of wood (usually a section of a tree), which forms the support, a little larger than the trough (*see* fig. 82), and wedges are driven in on one or both wides of the trough, so as to keep the joints between the bottom and sides of the trough from opening out and leaking. The tighter the wedges are driven in the less will be the leakage. The blocks of wood into which the trough is notched are embedded partially or entirely in the ground; or else are supported upon wooden trestles of varying height, or rest upon embankments, so as to make the gradient of the slide as uniform as possible.

Alignment of a wet wooden slide.—In selecting the line for a wet wooden slide, the best alignment would be one which is quite straight and in which the gradient, if not uniform, is steeper on the upper portion of the line. If it is not practicable to get a perfectly straight line, then the slide should be aligned so as to have a constant down gradient as far as practicable, and where the natural obstacles met with necessitate a change of gradient, that change should be very gradual. The curves given to the slide depend upon the length of the scantlings to be taken down and should be such that the descending timber moves round the curves without impinging violently against the outer side of the slide.

The constant down gradient is obtained either by cutting a track out of the hill-side in which the trough is embedded, or by supporting the trough on stone embankments or wooden trestles.

Wooden trestles have been found to be less expensive and preferable in every way to stone embankments. The former being more elastic, give more to the descending scantlings and consequently remain more water-tight.

A good type of wooden trestle is shown in figure 83.

FIG. 83.

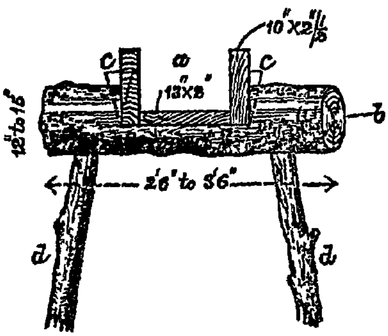


Figure 83 is a cross-section of a wet slide erected in the Mandi State, North-West Himalaya. The trough a *is supported on blocks of wood* b, *as shown in the sketch. The side and bottom are kept together by means of wedges* c, c *driven into the blocks on either side of the trough itself. The blocks are either laid on the ground or supported on trestles* b, b, *as shown in the figure. (From the* "Indian Forester" *for May 1889.)*

The construction of this trestle is given in detail in Appendix IV, page 365.

Wet slides should be made in sections, the length of which depends to some extent on the nature of the ground traversed. The length of a section should not exceed half a mile. If wet wooden slides are made in sections, the difficulty of supplying them with a sufficient quantity of water is much lessened; difficult places on the line may be avoided and some more suitable mechanical means of transport introduced; if one section of the slide is damaged, the other sections can be worked as usual, and the scantlings carried over the broken section. The sleepers do not attain so great a velocity when the length of the slide is short, and the wear and tear on the slide itself is consequently less.

Water-supply.—Since wet slides must have a plentiful supply of water, especially when the gradient is low, they must follow more or less closely the course of a stream, and will often have to cross and re-cross it, in order to avoid the construction of very sharp curves. The supply of water admitted at the

head of a slide is rarely sufficient, if the slide is a long one, to take the sleepers or scantlings down to the end of the slide on account of leakage; and fresh supplies of water have to be brought to the slide whenever the supply of water falls short, so that there may always be plenty of water in the slide where the gradients are low. Even when the trough is not used for sliding, there should be a sufficient quantity of water running down the slide to keep it thoroughly wet, and to prevent the joints between the sides and the bottom of the slide from opening out.

§ 84. TIMBER OR FIREWOOD SHOOTS.—A timber or firewood shoot is practically a short slide which may be either dry or wet. A shoot differs from a slide, in that it is laid down in an exact straight line, with few, if any, changes of gradient.

Shoots may be used for launching sleepers or other scantlings down a steep bank into the river, down which they are to be drifted; or else for the transport of fuel from a higher to a lower level, as, for example, from a cart road into a fuel godown at a lower elevation, which is not accessible to carts.

The gradient of the lower part of a shoot is very low, and the end portion may be perfectly level or even slightly turned up to obviate breakages. The trough forming the shoot is constructed in a similar way to that of an ordinary wet slide, but is more firmly put together, and should be strengthened by the addition of long iron bolts introduced midway between the wooden blocks into which the trough is fixed. These bolts pass through the base and the side pieces of the trough. The latter, where practicable, is placed in the ground, in order to offer greater resistance to the impact of the scantlings against its sides.

§ 85. TIMBER SHOOTS.—These have been used in India since 1872 and have been found to answer very satisfactorily the purpose for which they have been constructed.

The *Mandhòle timber shoot* made in 1872 was 848 feet long. The joints between the side pieces were dovetailed into one another. Bolts passing through the base and side

of the slide were added at intervals, so as to make the trough as strong as possible. Three thousand sleepers could be launched in one day.

The *Thadiar timber shoot* was 333 feet long, the inside measurements of the trough being 10 inches in width by 8 inches in depth. The upper 234 feet has a gradient of 42 degrees, while the lower 90 feet was given one of 26 degrees. The trough was constructed of scantlings 4 inches thick. The end of the shoot was bent slightly upwards so as to allow the sleepers to fall into the water broadside on, instead of end on. A pool 6 feet deep was maintained in the river where the shoot was erected, by the construction of a temporary dam across part of the river. A depth of 6 feet was found sufficient to prevent the sleepers from being damaged.

An average of 2,700 sleepers *per diem* were launched by means of this shoot between the 22nd January and the 12th February 1890.

The trough was kept together, as in wet slides, by wedges driven into notches cut in the blocks of wood in which the trough is fixed. The blocks were placed where either the side or the bottom pieces were joined. The wedges had to be tightened from time to time when the sleepers were being launched as they worked loose.

A little water is led into the top of the shoot, to keep it permanently wet, so as to prevent its being set on fire when in use.

The ends of the sleepers ploughed into the bottom plank on the shoot, at the point where the shoot was bent upwards, but did not otherwise materially injure it. At this point the bottom piece of the shoot was made 6 inches deep instead of four, and when it was worn down to a depth of 2 inches it was renewed. This scantling had to be renewed weekly when the shoot was in use.

The cost of constructing, renewing and repairing the shoot between April 1890 and December 1893 was R861, while the cost of launching 344,500 sleepers during the same period amounted to 4 annas per hundred.

SECTION VII.—WIRE-ROPE WAYS.

§ 86. Wire-rope ways are now largely used for the transport of ore and other materials, and their adoption has generally materially reduced the cost of transport of the produce concerned and, by so doing, allowed of the development of industries which otherwise could not have been profitably undertaken.

Wire-rope ways have been profitably employed in the development of quarries; in a great variety of manufacturing industries, such as cement works, brick-fields, saw-mills, breweries, textile factories, etc.; on coffee, tea and sugar plantations; and for the transport of timber and fuel.

§ 87. As far as the transport of forest produce is concerned, wire-rope ways have, so far, only been used for the carriage of timber and firewood down steep hill-sides or across deep valleys.

Timber, firewood and other forest produce can be transported over wire-rope ways down slopes which are too steep to allow of the construction of sledge roads or slides; and also from the top to the bottom of precipices down which it would be impossible to carry the timber by any other means. In India, as a general rule, wire ropes will not be required for the transport of logs, because the trees are usually converted in the forest.

The ropes down which the produce travels may be stretched in one or more spans, and may be supported at intervals where the nature of the ground is such that the introduction of intermediate supports is necessary. When intermediate supports are used, special arrangements are necessary to allow of the loads passing over them.

Where the nature of the ground is such that intermediate supports must be introduced and at the same time the inclination of the rope is so steep that a guide rope is necessary, the fixed-wire rope must be laid down in a perfectly straight line.

One of the great objections to the general introduction of wire-rope ways for the transport of forest produce is, that it is necessary for the smooth working of the line that the rope should be perfectly straight, without any curves in it. Where it is

necessary to change the direction of the line, the carrier may be shunted on to a rail and thence on to another rope-way diverging in a straight line from the first one. Every curve consequently necessitates an additional station for straining the new length of rope and adds considerably to the initial cost of the line as well as to the wear and tear of the guide rope and carriers, and to the difficulty of working the line.

§ 88. ADVANTAGES OF WIRE-ROPE WAYS.—So far as transport of forest produce in India is concerned, the wire-rope ways can be most advantageously introduced in hilly districts for the carriage of timber, fuel, etc., from a higher to a lower level, where the descending load will travel in virtue of its own weight and will not require any additional motive force.

They may also be of use in lifting forest produce over a ridge where the other alternatives are to make a tunnel through it, or a devious path or road round it.

The principal advantages of wire-rope ways in the transport of forest produce are—

(1) That the gradient permissible on a wire-rope way is much greater than those allowed on paths, sledge roads and slides, and that produce can be carried from the top to the bottom of a precipice by a wire-rope way, which could not be negotiated in any other way.

(2) That river and ravines can be crossed without descending to the bed of river or ravine and ascending again on the other side.

(3) That the lines can be moved from one place to another with comparative facility.

(4) That the lines do not occupy any material quantity of ground, as they are supported upon supports placed at considerable distances apart.

(5) That floods and heavy falls of snow do not interfere with the working of the line.

§ 89. SYSTEMS OF WIRE-ROPE WAYS.—So far as forest transport in India is concerned, it must be remembered that under ordi-

nary circumstances only the simplest and cheapest of mechanical means of transport can be profitably introduced, as it is necessary (*see* page 4, § 4) that the direct savings in the cost of transport by the mechanical means introduced must more than cover the initial cost of the installation and its upkeep within a short term of years.

Wire-rope ways are divided by Mr. A. J. Wallis-Tayler [1] into two principal classes:—

(1) Where a running or travelling endless rope, supporting and moving the carriers, is employed;

(2) Where a fixed carrying rope and a light running or travelling hauling rope, attached to the carriers by couplings or grips, is used.

Mr. W. T. H. Carrington, C.E., A.M.I.C.E., a well known authority on wire-rope ways, divides the first class into two systems: [2]—

(1) Where an endless running rope, with the carriers detachably connected to the rope by means of saddles, is used;

(2) Where an endless rope, with the carriers rigidly fixed in position on the rope, is used;

and the second class into the three systems which consist of—

(3) One single fixed rope, with *one carrier* drawn from one terminus to the other, and *vice versâ*, by an endless hauling rope.

(4) Two fixed ropes, with *carriers* mounted on trucks or runners, and detachably secured at predetermined intervals to an endless hauling rope. The runners of the carriers moving over the fixed ropes.

(5) Two fixed carrying ropes, with an endless hauling rope by which *one carrier* is drawn in one direction upon one carrying rope, while the other carrier is drawn in the opposite direction upon the other carrying rope.

To these systems must be added the simplest of all wire-rope ways.

[1] Aerial or wire-rope Tramways, their construction and management by Mr. A. J. Wallis-Tayler, C.E., A.M.I.C.E., page 6. (London, Crossby, Lockwood & Son, 1898.)

[2] Mr. Wallis-Tayler, *op. cit.*, page 7.

(6) A single fixed rope, with *no* guide line, where the runners of the carriers to which the loads are attached move over the fixed rope.

On the Continent of Europe two systems of wire-rope ways, which differ from those above given, chiefly in that the guide line is not an endless rope, have been used for the transport of timber.

(7) A single fixed carrying rope with a moving guide line about the same length as the fixed rope, one end of which is firmly attached to a carrier. Two carriers only are used.

(8) Two fixed carrying ropes and two guide lines about the same length as the fixed carrying ropes. Two carriers move on the fixed carrying ropes in opposite directions.

In Switzerland, where transport by wire ropes has been successfully used for the transport of timber and firewood, the rope-ways now in general use belong either to system (4) or system (6).

The fourth system is used on main lines for the transport of timber, and the sixth system is used in the construction of feeder lines and for the transport of fuel.

Simple fixed ropes can be used for the transport of timber, fuel, etc., so long as the gradient is so regulated that the descending load comes to rest, or is moving very slowly when it reaches the lower end of the rope-way. Where the gradient is too steep to allow of this being done, a guide line is necessary in order to control the speed of the descending load and to ensure its just reaching the lower termination of the rope-way.

The different systems of rope-ways enumerated above have been evolved to meet the existing requirements of transport, and it is necessary, in order to avoid the risk of failure, to adopt that system of wire-rope way which is best suited to the requirements of the case.

§ 90. BRIEF DESCRIPTION OF CARRINGTON'S FIVE SYSTEMS OF WIRE-ROPE WAYS ENUMERATED IN § 89[1]—Systems 1 and 2 are simpler in construction than systems 3, 4 and 5. The total amount of material to be carried over them in a working day of 10 hours must not exceed 500 tons, nor *must the individual load be more than 6 cwts. (732 lbs.).* The intermediate supports should not be more than 600 feet apart, and, if possible, they should be placed at intervals about 200 feet.

The endless rope passes round wheels or drums from 6 to 10 feet in diameter at either end of the line. At one end of the line a driving gear (if necessary) is placed to rotate the drum, round which the endless rope passes, and the wheel or drum at the other end of the line is provided with tightening gear. The loads are carried in boxes hung on the rope by means of saddles at the loading end in such a way as to maintain them in a state of perfect equilibrium and to allow of them passing over the intermediate supports.

The gradient of the rope in the first system must not exceed 1 in 3.

The second system differs from the first in that the carriers are rigidly secured to the rope by a steel band or clip so that they are fixed in position and must follow the rope passing round the wheels at the terminals instead of running on to shunt rails as in the first system. This modification allows of any gradient being given to the rope, and also of sudden and continual changes in the vertical angle of the line being made at each intermediate support, if necessary, by the use of guard or depressing pulleys.

Systems 3, 4 and 5 allow of very long spans being erected without intermediate supports. One span of 6,000 feet has been erected across the Via Mala, near Thusis, in Switzerland. Wherever sufficient fall occurs and it is required to transport goods from a higher to a lower level, the power of gravity due to the descending loads can be utilized to raise the empty carriers, and no additional motive force will be required. Where the

[1] Mr. Wallis-Tayler, *op. cit.*, pages 7—13.

loads have to be carried up hill, or in the case of a single fixed carrying rope, motive power is necessary.

System 3 is best suited for cases where only moderate quantities of materials have to be carried, the individual loads being heavy, the spans long and the inclines steep. The single carrier travels over the fixed rope and is drawn backwards and forwards by means of an endless rope operated by suitable reversing gear at one end and tightening gear at the other. The fixed carrying rope is supported on posts about 300 feet apart. The hauling rope passes over pulleys fitted with guide bars located in the centre of the standard over which the carrier passes. The carrier passes through the standards, the return portion of the hauling rope passes on outside pulleys carried by brackets fixed on to the outside of the intermediate supports.

System 4.—This system is desirable when over 500 tons of material have to be carried per diem and where the individual loads exceed 6 cwts. (1,464 lbs.). The inclines may exceed 1 : 2 and the span 1,000 feet. Two fixed ropes are stretched parallel to each other about 7 feet apart and supported by standards about 300 feet apart.

The fixed carrying ropes are anchored at one of the terminals and are provided with some suitable form of tightening gear at the other. The runners of the carriers consist of grooved steel wheels fitting on the fixed ropes, the receptacles being suspended from the runners by means of frames constructed so as to pass by the intermediate supports upon which the fixed ropes rest. The carriers are fastened immovably to the endless hauling rope by some suitable locking grip. The endless rope passes round wheels at either end of the line furnished with driving gear at one end, if necessary, and a tightening gear at the other end. This system of wire-rope way is economical in wear and tear, but somewhat expensive in first cost and is unsuitable where there are sudden changes in the vertical angle of the line.

System 5.—This system consists of two fixed carrying ropes, and two carriers, one moving upon one carrying rope, while the other moves down upon the other and *vice versâ*. It can be used where the spans are very long and the individual loads very heavy. The two fixed carrying ropes are stretched side by side

as in system 4, but only two carriers are used. These lines are usually self-operating inclines, the loaded carrier descending and hauling up the empty or more lightly loaded carrier, which in its turn is loaded and descends. When the loaded carrier passes up, and the empty or lightly loaded carrier descends, power is used. The travelling speed may be as much as 30 or 40 miles an hour. The individual loads may be 3 tons or more and the spans traversed over 3,000 feet. This type of line is cheaper than system 4 in first cost and also in maintenance, and fewer hands are required to work it. The quantity of material it is capable of carrying per diem is of course less, and the speed of running produces a rapid wear of the rope.

§ 91. Brief description of other Systems of wire-rope ways :—*System 6.*—A single fixed rope can only be used for the transport of forest produce down hill. The rope must be in a straight line, and the gradient of the line such that the descending load just reaches the lower end of the fixed rope moving very slowly. In the case of firewood which is not much damaged if it strikes forcibly against an obstacle, the gradient of the line may be much steeper and the load of fuel brought to rest by impinging against a heap of earth or fascines. At present such inclined wire-rope ways have been laid out in straight lines, and where it is necessary to change the direction a second line is erected in the required direction, making an angle with the first, and the loads are transferred from one line to the other by hand.

System 7.—In this type there is a single fixed carrying rope and a guide or travelling rope about the same length. The laden carrier descends on the fixed wire at the same time that the empty carrier ascends. There are only two carriers used; each is attached to one end of the travelling rope. One carrier is at the top of the rope when the other is at the bottom. Where the carriers pass each other, the empty one rises off the fixed wire rope (*see* fig. 98, page 169) on to a hinged rod which allows of its falling on to the rope again, while the descending loaded carrier pushes up the end of the hinged rod which rests on the fixed rope, and passes underneath it and continues its

descent. The fixed carrying rope may be supported, where required, by the nature of the ground passed over.

System 8.—The two fixed carrying ropes are parallel to each other. The two guide ropes are fastened to and wound round a roller at the upper end in opposite directions, so that one rope is wound up by the other as it unwinds. When one guide rope is entirely wound up the other is quite unwound. The ends of these guide ropes are attached, one to each of the two carriers which work on the fixed ropes. One carrier is at the top of the rope-way when the other is at the bottom and the descending loaded carrier automatically draws the empty carrier up the second fixed rope to the top of the wire-rope way.

Of the systems of wire-rope ways described above, only numbers 4, 6, 7 and 8 have been utilized in the transport of forest produce. System No. 4 is used generally in Switzerland on important wire-rope ways, and No. 6 is considerably used for the transport of fuel and as feeder lines to the main wire-rope ways. The latter system is used in Ceylon for the transport of fuel and tea leaf, and in India for the carriage of tea leaf and coffee berries.

§ 92. A SINGLE FIXED INCLINED WIRE ROPE.—In this system the speed with which the loaded runner or carrier, to which the produce to be transported is suspended, passes down the rope is not controlled in any way. In consequence the inclination given to the rope, and the nature of the carrier used, must be such that the load comes to rest of its own accord, just as it reaches the lower end of the inclined wire rope. If the load has still a considerable velocity when it reaches the bottom of the span, the transported material, except in the case of firewood, is liable to be more or less seriously damaged. If the carrier is furnished with a wheel (as is generally the case), which runs on the fixed inclined wire rope, the gradient of the rope must be a low one (as the friction between the revolving wheel and the fixed inclined rope will be very small, especially if both wheel and rope are made of metal). The velocity of the falling body will be proportionately great.

In this class, intermediate supports may be introduced where required, so long as *wheeled* carriers are used. The loops of the fixed rope between the different intermediate supports should be in the same straight line. So long as the gradient of the fixed inclined rope is kept low, any number of intermediate supports may be introduced. The gradient of the different loops should be such that the descending load is moving slowly when it reaches the several supports on the line.

Where the inclination of the rope is too great to allow of this, the velocity of the descending load must be controlled by means of a guide rope.

Hooks or blocks, made of brass or soft iron, may be used where the gradients are moderately steep, but if the gradient is very steep, wooden blocks must be substituted so as to increase the friction and decrease the velocity with which the loaded carrier will move down the rope.

The steeper the inclination the greater must be the surface of the block in contact with the inclined wire. If the wooden blocks are soaked in water before use, the resistance to the downward motion of the falling body is increased. Wooden blocks have an advantage over metal ones, in that the wear and tear is principally confined to the blocks themselves, and the fixed steel wire is in consequence very little worn by the passage of the loads down it.

The wire, unless kept taut by artificial means, hangs in a loop, so that the actual inclination of the upper portion of the wire rope is more, and that of the lower portion less, than the *mean* gradient, *i.e.* the inclination of a line drawn straight between the ends of the stretched rope.

At Bamsu, Jaunsar Division, the upper two-thirds of each loop had practically an inclination greater than the mean, and the lower one-third an inclination less than the mean inclination of the rope.

Besides the gradient and the nature of the carrier, the velocity with which the descending body will travel depends also upon (1) its weight, and (2) its bulk.

The greater the weight of a body of given volume and shape the greater will be the velocity acquired by it in falling. On the other hand, the greater the surface presented to the air by the falling body the less will be the velocity acquired. A scantling descending end on will travel faster than one which descends broad-side on.

The upper end of the fixed carrying rope should be securely anchored in the ground, or to a suitable tree if one is available.

Figure 84 shows the anchorage of the upper end of the Bamsu wire-rope way. The rope is wound round a horizontal beam resting in the forks made by two inclined beams notched on to each other. These inclined beams are embedded in a large mass of masonry. The rope is then passed round a tree *two or three times, wound round itself and then securely bound* round with a piece of thin wire.

This method of anchorage is unnecessarily strong. The top of an inclined wire-rope way may be safely anchored in either of the methods in which the longitudinal ropes of a suspension bridge are anchored (*see* Volume II, § 153, page 184, *et seq.*).

In the Darjeeling district, several simple wire ropes have been erected to carry tea leaf from tea gardens to the factories. The upper end of the rope is anchored to an iron rod, ending in an eye, while the lower end is attached to a similar rod fastened to an iron plate ½ an inch thick and 2 to 3 feet square. This rod is 10 feet long. It is placed vertically in a hole dug in the ground and the hole filled in with dry rubble masonry, the eye of the bolt being just above the ground. The anchoring rod is 1¼ inches in diameter, a shackle is placed in the eye of the anchoring rod and the fixed carrying rope is fastened rigidly to this shackle. The ropes on the Tungsong Tea Estate, Darjeeling district, are fastened by passing the end of the rope round an eye and between two grooved plates which are fastened together by screw-bolts passing through their edges. The shackle of the anchoring rod is passed through the eye of the plates, which clamp the end of the rope, and through the eye of the anchoring rod.

FIG. 84.

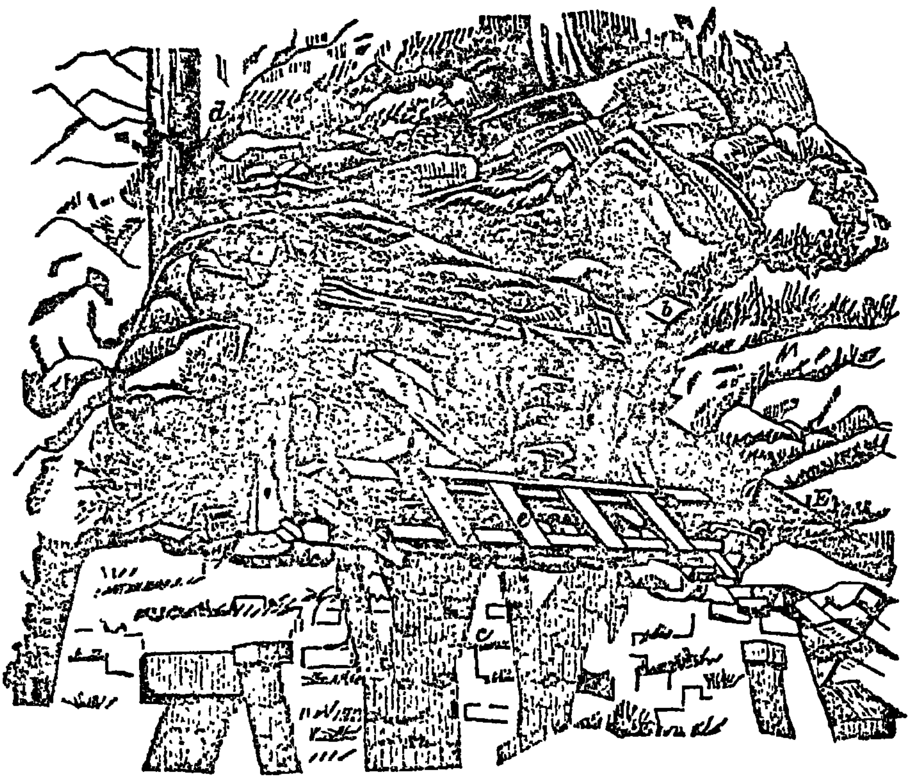


Figure 84 shows the method of fixing the upper end of the fixed inclined wire rope adopted at the top of the first span at Bamsu. The rope E is passed twice round the horizontal beam a, *which rests on the two supports* b, b *embedded to a depth of 6 ft. in a mass of masonry* c. *The rope is then passed round the stem of a tree* d *and fastened to itself. The framework* e *is placed to give standing room to the men who fix the sleepers on to the rope and start them. The horizontal beam and the beams of which its supports are made are about 10 inches square and are made of deodar. (From a photograph.)*

The rope might be fastened by being passed directly through the eye of the anchoring rod and secured in the same way as the suspender of a suspension bridge (*see* Volume II, § 155, page 190, *et seq.*).

§ 93. The lower end of the fixed rope should be anchored in such a way as to allow of its being lengthened or shortened, as may be found necessary.

FIG. 85.

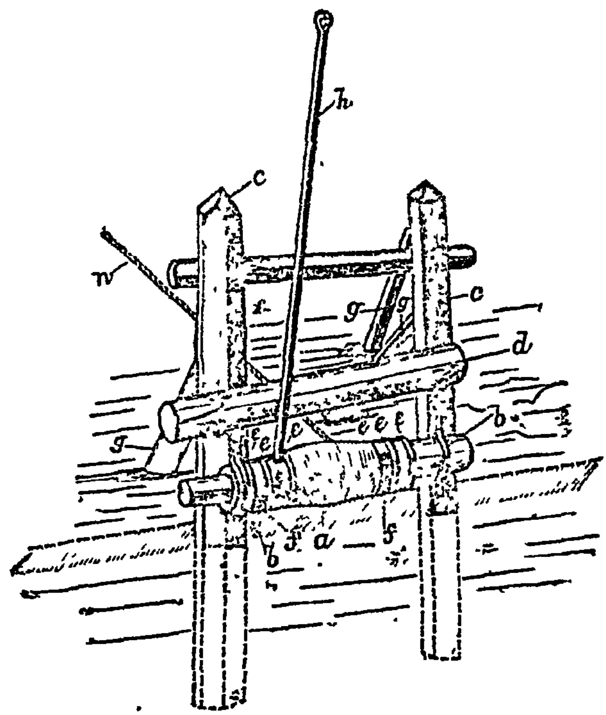


Figure 85 shows a method of anchoring a fixed wire rope used in Switzerland. n is the fixed carrying rope; a is the log to which it is fastened, and round which it is wound; b, b are the loops of iron spiked on to the slanting posts c, c, in which the ends of the log rest. The slanting posts c, c are firmly embedded in the ground; d, is the horizontal log against which the lever h presses and keeps the rope from unwinding; e, e, e, e are iron bands shrunk on to the horizontal log to strengthen it; g, g, g are struts which strengthen the inclined logs and prevent their being pulled over by the rope; h is the lever used by means of which the rope n is loosened or tightened, as the case may be. (From a photograph).

Figure 85 shows the method of anchoring the lower end of fixed wire ropes which is generally used in Switzerland. The illustration shows the anchorage of the middle span of a wire-rope way in the Pontironé Valley near Biasco, south of the San Gothard tunnel. The wire ropes are 2 miles long and rest on several intermediate supports, the speed of the descending loads being controlled by an endless guide rope.

The fixed carrying rope (*n*, fig. 85) is fastened to and wound round a log (*a*, fig. 85) which rotates on a horizontal axis. The ends of this log rest in loops (*b*, *b*, fig. 85) of iron 2⅜ inches (6 centimetres) wide and ⅜ inch (½ centimetre) thick, which are fastened by four spikes to two posts (*c*, *c*, fig. 85) 39 inches (1 metre) in girth, firmly embedded in the ground and inclined over the horizontal log round which the fixed rope is wound, similarly to the slanting posts of the anchorage of a suspension bridge (*see* Volume II, page 186, fig. 89). The ends of the horizontal log (*d*, fig. 85) also rest against the inclined posts. The horizontal log is strengthened by 6 hoops of iron 1½ inches (4 centimetres) wide and ⅜ inch (½ centimetre) thick (*e*, *e*, *e*, *e*, *e*, *e*, fig. 85) shrunk on to it. Three of these hoops are placed near either end of the log, leaving the central portion free for the reception of the fixed wire rope. Between the second and third band near either end of the horizontal log four holes (*f*, *f*) are cut in the log to receive the ends of the long levers by means of which the log is rotated and the rope loosened or tightened as may be required.

The fixed rope is kept from unwinding itself by one or two levers placed in the holes (*f*, *f*) and resting against a log (*d*, fig. 85) which is 2 feet (60 centimetres) in girth, which in its turn is jammed against the two inclined posts (*c*, *c*, fig. 85) These inclined posts are strutted (*g*, *g*, *g*, fig. 85) so as to take the strain to which they are subjected. Two long-eyed levers, about 9¾ feet (3 metres) long, are required in order to tighten the rope.

The method of tightening the rope is as follows.—A stout rope is passed through the eye of each lever. The two levers are

placed into one log. Each lever in turn is placed in a vertical position against the pole (*h*, fig. 85) and is pulled down into a horizontal position, so causing the log round which the wire is wound to rotate and in turning round to wind up the fixed wire.

When one lever has been drawn down into a horizontal position, the log is held tight by the other lever, while the horizontal lever is removed from the hole it is in and placed vertically, or nearly vertically, in another hole, and this process is repeated until the rope is sufficiently tightened. One of the levers or a stout crowbar is then placed as nearly vertical as possible into one of the holes in the log and is gradually released until it rests against the pole (*d*, fig. 85) and thus fixes the rope.

Eighteen men were required to tighten a fixed wire rope which was 2 miles long and was 2¼ inches in circumference in the Pontironé Valley (Switzerland).

§ 94. INTERMEDIATE SUPPORTS OR STANDARDS.—Single fixed wire-rope ways may sometimes consist of one long loop without any intermediate supports; but usually the configuration of the ground is such that intermediate supports are necessary. The distance between the intermediate supports or *standards* depends upon the configuration of the ground. In Switzerland, where the transport of forest and other produce by wire-rope ways has been more developed than in any other country, the intermediate supports are not placed at fixed intervals apart, but are introduced wherever the fixed or guide rope would otherwise touch the ground. At such points a standard is introduced to allow of the load passing over the line without striking against the ground and to prevent the ropes being dragged along the ground.

Again, where there is a considerable increase in the gradient of the line, two or three standards about 100 or 200 feet apart are erected just above the point where the steep incline begins. In the Pontironé Valley the wire-rope way follows along the valley with a gradient varying from 5° to 13° (8·7 in 100 to 23 in 100) and then drops down to the main valley with a gradient of about

30° (57·7 in 100), and there are standards about 200 feet apart where this great change in the vertical angle takes place.

If two standards close to each other are erected where there is a sudden change in the vertical angle of the line, the working of the rope-way is found to be much easier, and there is no tendency for the load to leave the line as there is when the angle changes suddenly at one standard from a gentle to a steep gradient.

Figure 86 shows the type of standard which is generally used in Switzerland.

The illustration shows part of one of the intermediate supports of a double fixed wire rope, with an endless guide rope (not shown) on the Pontironé wire-rope way, Ticino Canton, looking down the line. The standard is made of poles 6 to 8 inches in diameter, bolted or spiked together. The fixed wire ropes rest on strong hooks (*a*, *a*) which are suspended from a horizontal beam *b*. This beam is bolted to two upright posts *d*, *d*, which are strutted on two sides to prevent their being overturned when the descending load passes down over one of the fixed wire ropes; *e*, *e*, *e* are struts; *f*, *f* are blocks of wood spiked on to the uprights *d*, *d* immediately under the cross-piece *b*, to support it. In earlier types of standards the hook (*a*, *a*, fig. 86), upon which the wire rope rests, was bolted through the upper beam (*b*, fig. 86) of the support, but it was found that the loads swayed sideways on the way down and sometimes left the line at the supports, so now the hook (*a*, fig. 86), upon which the fixed carrying rope rests, is hinged on to the eye-bolt (*c*, *c*, fig. 86), to allow of its oscillating with the descending load.

The end of the hook on which the rope rests is narrowed and elongated so as to form a bed for the wire rope. The hook is made out of bar iron 1½ inches in diameter. The bed on which the wire rests is 2 inches long and ½ an inch wide. A groove is cut in this bed for the rope, which is half embedded in the supports, while the upper half of the fixed wire rope projects above the hook.

FIG. 86.

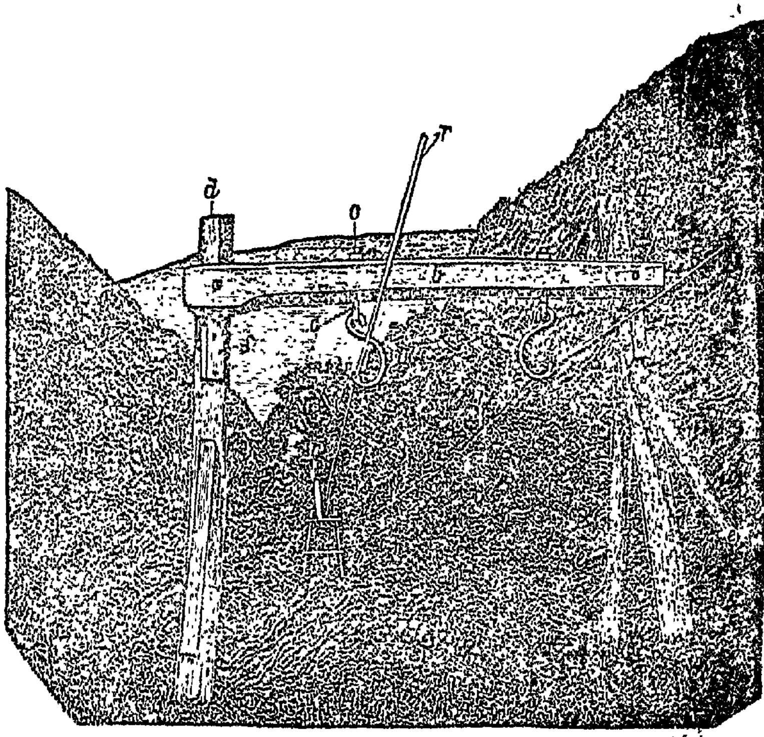
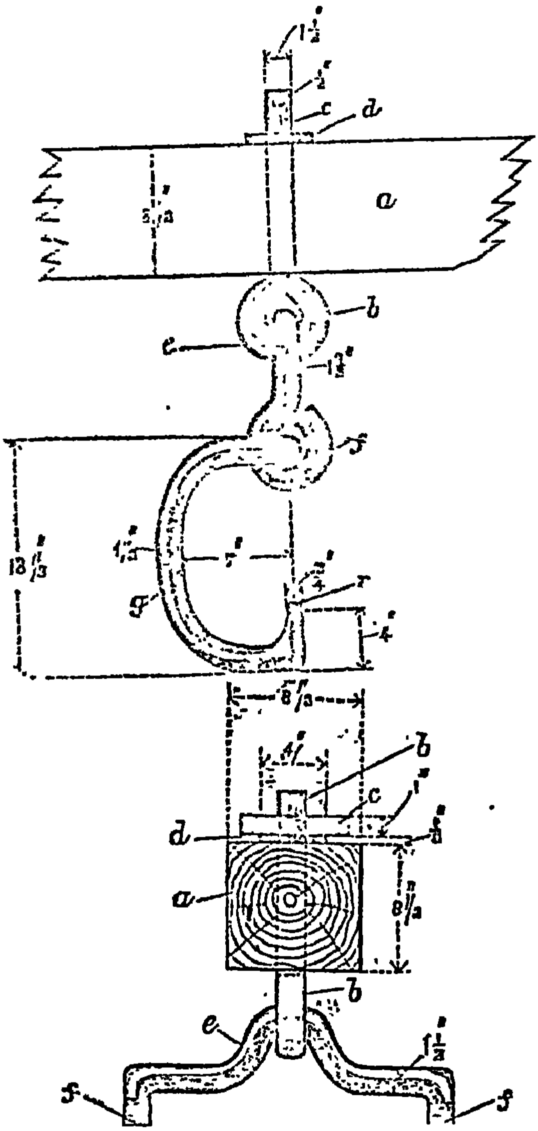


Figure 86 shows two intermediate supports on the Pontironé wire-rope way. r, r *are the two fixed carrying ropes. They rest on hook supports* a, a *hinged on to eye-bolts* c, c *which are bolted through the horizontal beam* b *of the standard.* d, d *are the uprights on to which the beam* b *is bolted.* f, f *are blocks of wood which help to support* b. *The struts* e, e, e *strengthen the uprights* d, d. *A second standard is seen in the middle distance at* g. *The wire ropes pass over the dip seen in the far distance and continue to descend the valley. (From a photograph.)*

In the latest type of hook support, the wire rests on two hooks suspended from the beam; the hooks are 21 inches apart and the support is shown in detail in figures 87 and 88, page 153. This type of support is now used where heavy loads pass down over a line, and it is stated to be a great improvement on the single hinged hook, in giving a better support to the fixed rope and in rendering the working of the line easier.

FIGS. 87 and 88.



In the case of a single fixed wire, the hook which carries the wire can be fixed to a simple wooden bracket fastened to a tree or to a single strutted upright, as may be most convenient. The hook should turn outwards from the tree.

The length of the individual spans depends, as has been noted above, upon the configuration of the ground passed over. A single span of 6,560 feet has been erected over the Vià Mala near Thusis, and they are commonly from 1,000 to 2,000 feet in length; so that the length of the spans may be said hardly to affect the construction of a wire-rope way.

§ 95. CARRIERS.—The vehicle or receptacle used for the conveyance of the produce, and the contrivance by which it is

Fig. 89.

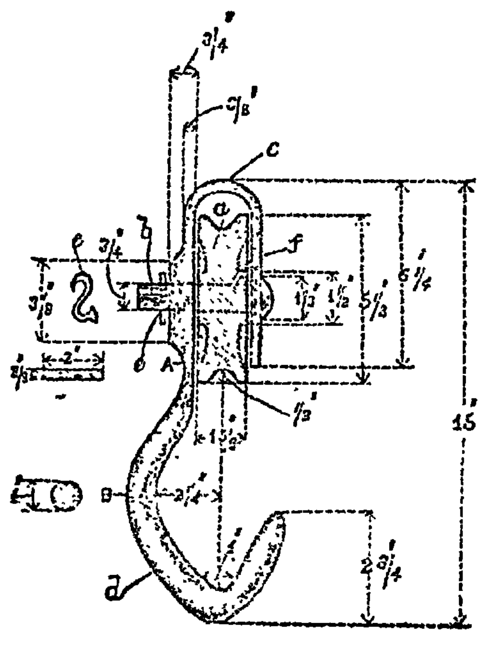


Figure 89 is a sectional elevation of the carrier in general use in Switzerland. a is the runner which moves on the fixed wire rope shown in section, b is the axle on which it rotates, f is a hole cut in the runner to allow of the axle being lubricated. c is the iron frame which supports the axle of the runner. The cross-sections of this frame at A and B are shown to show its shape. One end of this frame is continued to form the hook d from which the load is suspended. The middle of the hook where the load rests is vertically below the centre of the runner. e is the French wire nail which keeps the axle pin in the frame. It is shown in detail at the side. Scale = $\frac{1}{5}$

suspended from the fixed wire rope, is known as the *carrier*. There are a number of different forms of carriers designed for the carriage of different kinds of material. Figure 89 shows the type of carrier in general use in Switzerland on double fixed rope-ways.

The carrier consists of a grooved wheel (*a*, Fig. 89) which runs on the fixed wire rope, and in descending rotates on its own axis. The pin *b* on which it rotates is horizontal and rests in a simple metal frame *c*, one side of which terminates in a hook *d*. The hook is slightly curved to allow of its passing round the end of the support upon which the wire rope rests. The frame and hook are beaten out of a bar of wrought iron, while the grooved wheel is of cast iron. The axle pin *c* is kept in position by a French wire nail *e* bent into the shape of the letter S. By straightening the nail, it can be withdrawn and the wheel separated from the frame which supports it. Two carriers are attached to each load. In forest work the load is usually attached to the hook of the runner by chains, and no special vehicle is suspended from it.

When the loads reach the lower end of the wire rope, they are lifted off the hook of the carrier without any difficulty.

§ 96. *Gradients on simple wire-rope ways.*—The gradient for wire-rope ways, where there is no guide line, must be so arranged that the descending load comes to rest at, or is moving very slowly when it reaches, the lower terminus of the line.

The gradient allowed depends upon the nature of the load, more especially its weight, and the nature of the carrier.

The carriers should as a rule be furnished with wheels which run upon the fixed carrying rope, except in temporary lines for the transport of fuel, which will be considered separately.

The experience gained on the Tungsong Tea Estate wire-rope ways, which were designed and erected by Mr. C. Brown, C.E., the Engineer of the Amalgamated Tea Companies, Limited (Darjeeling District), shows that the steepest mean gradient for a single wire rope carrying a load of 1 maund (82 lbs.) of tea leaf is 10° 20' (18 in 100). The following table shows the

approximate lengths and gradients of wire-rope ways, on the Tungsong Tea Estate:—

Span number.	Approximate length, in feet.	Gradient.			Load, in lbs.	Fall, in feet.
		Mean.	Of upper portion.	Of lower portion.		
1	5,000	10°·20′	...	2°·5′	82	700
2	4,500	12°·40′	...	5°·40′	50—60	...
3	1,320	11°·50′	12°·50′	9°·40′	50—82	250
4	1,200	10°·30′	12°·30′	6°·40′	50—82	150

The gradient of the 2nd span was too steep to allow of a load of 80 lbs. coming down, and the eight had to be reduced to 50 lbs. to prevent the leaf from being bruised.

The lowest mean gradient down which a load of 1 maund of tea leaf will move by itself is 6° (10·5 in 100), stretched so tight that the lower end of the line has a down gradient of at least 1° (1·7 in 100). Loads varying from 55—130 lbs. of tea leaf were tried on a wire-rope way which was about 3,000 feet long with a mean down gradient of 5° (8·7 in 100), the upper portion of the line having a gradient of 9°·20′ and the lower portion being horizontal, but they came to rest about 100 yards from the lower end of the rope-way, the weight of the load depressing the fixed wire rope and causing it to slope slightly *upwards* towards its lower end.

In the Bamsu Valley, Jaunsar Forest Division (North-West Provinces), a wire rope was erected to carry sleepers down a very precipitous slope uniting two sledge roads. A full description of this wire-rope way will be found in Appendix V, page 374. This wire-rope way consisted of 3 sections, as it was not found practicable to lay it out in one straight line.

The mean gradient of the upper span, which was 634 feet long, was 26° (48·8 in 100), that of the steep upper portion being 29½° (56·6 in 100), and that of the lower flatter portion 20° (36·4 in 100). The lowest span was 432 feet long and had a mean gradient of 27° (51 in 100), that of the upper portion of the

line being 29° (55·4 in 100), and that of the lower portion 23° (42·4 in 100). The middle span had a steeper gradient and was eventually worked with an endless moving line with two carriers fixed to it (system 2).

Carriers with wheeled runners and metal hooks were first tried, but it was found that the gradient of the rope was too steep and the sleepers reached the bottom of the line with great velocity. Eventually blocks of moru oak (*Quercus dilatata*) about 2½ inches square and 7 to 8 inches long were used as

FIG. 90.

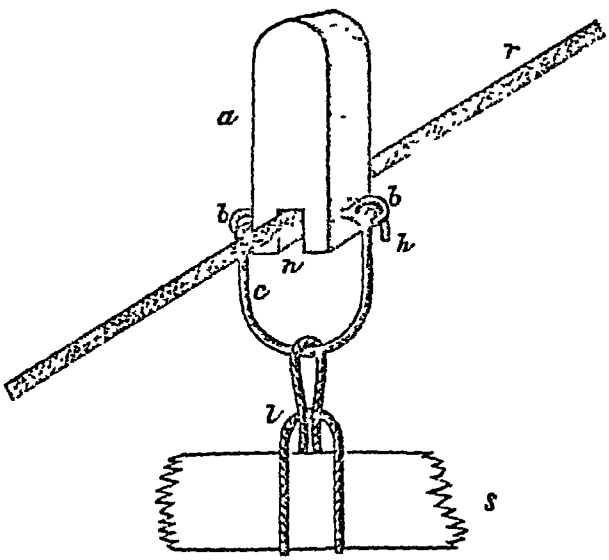


Figure 90 shows the wooden block used as a carrier on the Bamsu inclined wire rope and the method of attaching the sleeper to it: a *is the block;* b b *the wire eyes to which the wire loop* c *is fastened;* h *the hook-end of the wire loop; this can be taken out of the eye through which it passes, and the block can then be lifted off the inclined wire rope. The sleeper* s, *only part of which is seen, is fastened by a loop of wire* l *which passes round the sleeper and through itself, and is then placed on the loop* c; n *is the notch cut in the block to fit on the inclined wire rope* r. *(Scale 2 inches = 1 foot.)*

carriers. A notch, $1\frac{1}{2}$ inches deep and three-fourths of an inch wide, is cut in the carrier to fit on to the wire rope. Two eyes of iron wire are fixed on to the sides of the block (*see* Fig. 90). They are driven into the side of the block and the points bent up so as not to touch the fixed wire.

A loop of wire is fixed on to one eye, and ends in a hook which can be placed into the other eye. A piece of rope is fastened round the middle of the sleeper, so that it hangs freely in a horizontal position. The wire loop is passed through the rope which is fastened round the sleeper and is then hooked on to the eye of the block. The sleeper is thus suspended in a horizontal position from the block. It is launched broadside on by two men. When a sleeper travels down in this position it comes to rest or is moving slowly by the time it reaches the bottom of the span. If it moves down end on, it reaches the lower end with considerable velocity and impinges against some poles placed in a slanting position to stop it.

The wooden blocks are burnt during their passage down the wire rope. If the notch is burnt straight up the block, it can be used for three trips down each of the three spans of the rope-way. A piece of wood is then fixed into the notch and the block can be used for three more trips. Sometimes the notch does not burn straight and the blocks do not then last so long.

Occasionally the sleepers fall off the rope owing to the notch burning towards one side and the block splitting in consequence. The iron portion of the block can be used several times. The average cost of a block is half an anna. The load is one metre-gauge sleeper (weight 60 lbs). Broad-gauge sleepers weighing 180 lbs. were tried, but were found to reach the bottom of the middle span with such velocity as to damage themselves considerably.

In Switzerland fuel is brought down over simple wire-rope ways, and the carrier is made of a forked branch cut so as to form a hook. The hook rests on the wire rope and the load of fuel, 66 lbs. (30 kilogrammes), is tied by a piece of string to the long arm of the hook. The hook lasts one trip and is then

thrown away. The wire-rope way hangs in one loop. The best gradient for such wire-rope ways is 30° (57·7 in 100).

The length of the hook is 10 inches (25 centimetres), the diameter of the branch used below the hook is $3\frac{1}{8}$ inches (8 centimetres) and its length is $2\frac{3}{8}$ inches (6 centimetres), and that of the two arms of the hook about $2\frac{3}{8}$ inches (6 centimetres).

§ 97. TWO FIXED CARRYING ROPES AND ONE ENDLESS GUIDE OR MOVING ROPE.—In this system there is no necessity for the construction of intermediate stations, unless they are rendered obligatory by the configuration of the ground, since the descending loaded carriers pass along one fixed wire and the ascending empty carriers over the other. This system is equally suitable for long, single unsupported spans, and for a series of spans when the inclination is too steep to allow loaded carriers descending uncontrolled *so long as the different loops are in one and the same straight line*. It is more expensive to construct than the single fixed rope system with a crossing station, but is much easier to work with *unskilled* labour.

The endless guide rope passes round sheaves (wheels with grooved rims) at the upper and lower ends of the fixed carrying ropes. The carriers to which the loads are attached move down one of the fixed carrying ropes, while the empty carriers move up the other. The carriers are fixed immovably to the guide rope and several loads descend the fixed carrying rope at the same time. The velocity of the descending loads is controlled by steel wood-lined band brakes applied to the sheaves round which the moving guide line passes. This system has been largely introduced into Switzerland for the transport of timber, firewood and other materials, and the information concerning the detailed construction and working of this system was obtained by the author during a tour in Switzerland in the summer of 1898, through the kindness of Monsieur Coaz, the Inspector General of Forests to the Swiss Republic, and the Forest Officers in whose districts the wire-rope ways had been erected.

All the Swiss wire-rope ways constructed on this system are in absolutely straight lines, and no attempt has been made to work round a corner. The rope-ways have been constructed to

carry wood from a higher to a lower level, and no additional motive power has been found necessary; on the other hand, brakes have in all cases been required to retard the speed of the descending loads. These brakes are sufficiently powerful to bring the descending loads to rest at any point on the line that may be required. The loads are put on at approximately equal intervals from each other, and when the line is in full working one empty carrier reaches the top at the same time that a full one arrives at the lower end. The distances between the carriers on the guide or moving rope is determined after a few trials.

No difficulty has been found in changing the vertical angle of the fixed wire ropes as may be required by the nature of the ground passed over, so long as 2 or 3 standards about 100 feet apart are erected, where there is a sudden increase in the gradient of the line. The loads moving down the steep gradients draw the loads over the spans which have low gradients, or even up slight rises.

Powerful and yet simple band brakes work on the sheaves at either end of the wire-rope way round which the endless guide line moves; but practically the velocity of the descending loads is controlled by the brake at the top of the rope-way.

With the exception of the wire-rope way near Brienz, there is no means of tightening the endless moving guide line; nor does this appear to be necessary where the gradients are such that a brake is required to check the velocity of the descending load. Under these circumstances the guide line may hang loosely below the fixed carrying ropes.

The sheaves are usually cast in two or three pieces and are bolted together round a steel axle pin at the site of rope-way.

§ 98. ANCHORAGE OF FIXED CARRYING ROPES.—The two parallel fixed carrying ropes are anchored in the same way as has been already fully described in § 93, page 148, and can be tightened or loosened as may be necessary by the method described on page 149.

§ 99. THE ENDLESS MOVING GUIDE-ROPE.—The endless moving rope is much lighter than the fixed carrying rope. The carriers are rigidly fastened to it (*see* Fig. 95, page 154), so that

by checking the speed at which the endless rope moves the speed of the descending load is also checked.

This endless guide-rope passes round one or two sheaves at either of the fixed wire rope, and fixed directly below them. Two sheaves are used on long wire ropes, especially if the loads transported by them are large. Each sheave has a notch to take the endless guide line and a smooth surface all round the periphery of the wheel against which a band brake can be applied.

Figure 91 shows the construction of the rim of a sheave with one notch for an endless wire.

FIG. 91.

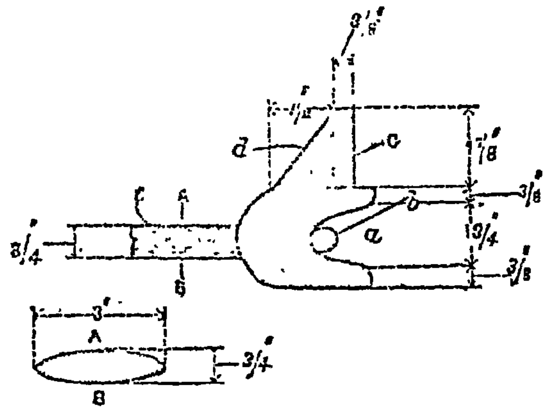


Figure 91 shows the construction of a rim of a sheave for the guide rope. The rim of the sheave is shown in cross-section, the spoke in elevation a *is the notch of the sheave in which the guide rope* b *moves;* c *is flat surface against which the band brake presses; it is strengthened at intervals along the rim by flanges shown at* d; e *is a part of one of the spokes of the sheave seen in elevation. The cross-section of this spoke is shown below. Scale = ¼.*

When the endless rope passes round two sheaves (*a* and *b*, fig. 92) the lower of the two sheaves *a* (at the bottom of a wire-rope way) must have two notches, as the endless rope passes directly on to the upper of these notches, goes round the sheave *b* and on to the second sheave *a*, and leaving that passes round the lower notch of the first sheave, and so leaves the

FIG. 92.

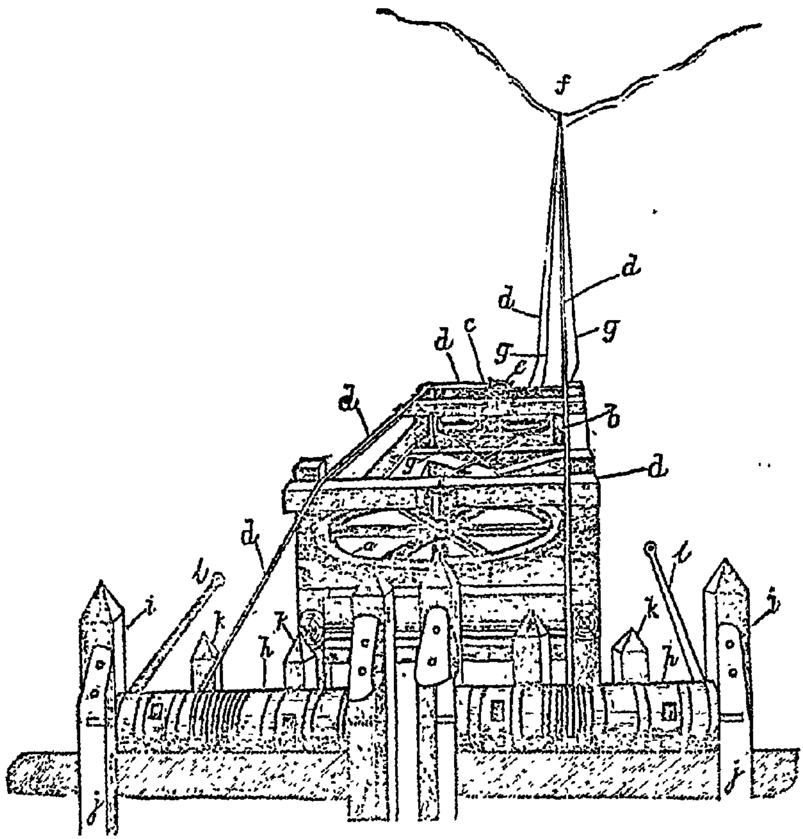


Figure 92 shows the anchorage of the fixed wire ropes and the method of supporting the sheaves round which the endless guide rope passes off the wire-rope way near Roche; a, b *are the sheaves round which the guide rope passes;* c, c *are the sockets in which the axles of the sheaves revolve;* d, d *are the two fixed carrying ropes which pass over the framework which support the sheaves and are fixed to two round logs in a manner similar to that described in § 93, page 148;* e *is the wheel of the screw by which the brake is put on or taken off;* f *is the upper end of the first span of the rope-way 1,000 feet away. The rollers* h, h *on which the fixed carrying ropes* d, d *are fixed, each rest against two slanting posts* i, i, *which are strengthened by the struts* j, j. *The posts* k, k *also prevent the logs* h, h *from being dragged out by the fixed wire ropes;* l, l *are the levers by means of which the fixed carrying ropes are tightened or loosened as may be required. (From a photograph.)*

anchorage. The guide line *g* is usually arranged in a figure of 8 round the two sheaves as is shown in figure 92, which represents the anchorage of the cable near Roche at the upper end of the Lake of Geneva.

The wire-rope way is 11,000 feet long and has 25 intermediate supports. The sheaves *a* and *b* are supported on a strong wooden structure made of roughly-squared logs bolted together. The sockets *c*, *c* which receive the axle of the sheaves are spiked on to beams of this framework.

The band brake is not seen in the figure, as it is applied to a flat surface on the sheaves below the groove in which the guide rope moves.

The plane of the sheaves is that of the mean gradient between the anchorage and the first support. The sheaves are always placed in this position, and are never horizontal. The brake on the cable near Roche is applied by screw power, the wheel by which the brake is applied is seen at *e* (fig. 92). On the other rope-ways visited the band brake was applied by a lever. One end of the brake is riveted to the wooden framework which supports the sheave, while the other end is fastened to the end of a bent lever (*a*, fig. 93) by means of which the band is pressed against the sheave. The band is $1\frac{5}{8}$ inches (4 centimetres) wide and $\frac{3}{8}$ inches (1 centimetre) thick; it is lined with a strip of wood $1\frac{5}{8}$ inches (4 centimetres) wide and $\frac{3}{4}$ of an inch (2 centimetres) thick throughout its entire length, and this strip of wood is brought into direct contact with the sheave.

FIG. 93.

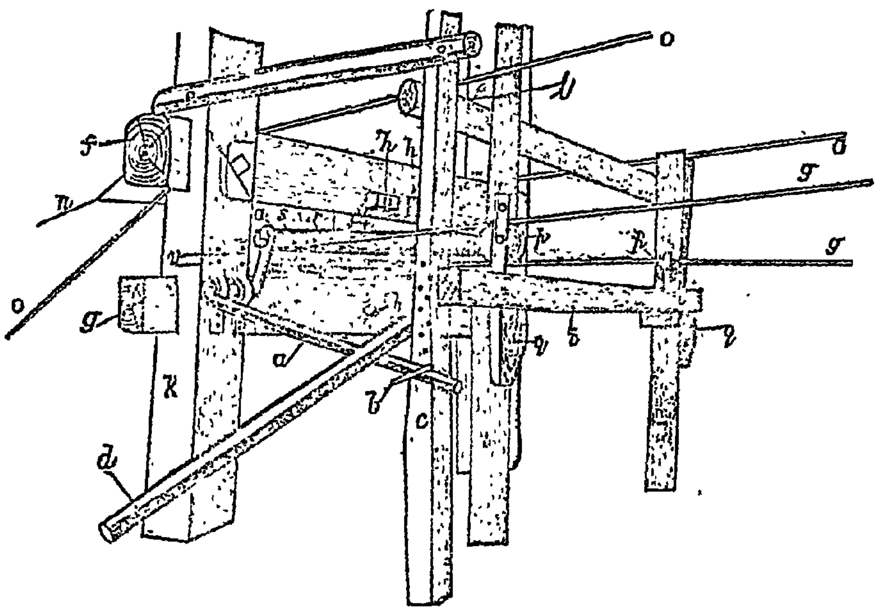


Figure 93 shows a brake at the top of a wire-rope way for controlling the working of the line ; s *is the sheave round which the guide rope* g *moves and to which the band brake* r *is applied. The axle* e *on which the sheave revolves is housed in two sockets bolted on to the back of the beams* f *and* g. *The ends of some of these bolts are seen at* h, h, h. *One end of the bent lever* a *is bolted to one iron end of the band brake and the other is fixed by the iron pin* b *which is placed in one or other of the holes bored in the post* e *to receive it. The brake is applied by pressing down the lever* d *which is bolted on to the beam* i. *The guide rope after leaving the sheave* s, *passes over two pulleys* p, p, *the supports of which are bolted on to the beam* i. *The beams* f *and* g *are bolted on to the posts* k *and* l *which are firmly embedded in the ground, are strutted to the posts* c *and* m *and tied by wires* (n), *only one of which is seen, to the anchorage of the fixed carrying ropes* o, o. *The brackets* q, q *are spiked on to the posts* t *and* m *to support the beam* i *which carries the pulleys over which the guide rope moves. The bent lever* a *works in sockets* v, v *spiked on to the post* k. *(From a photograph.)*

When the brake is put on, the lever is kept from moving by means of an iron pin (*b*, fig. 93) which is placed into one of the holes bored in an upright (*c*, fig. 93) of the wooden support of the sheave. The brake is kept pressed against the wheel when the rope-way is not working. When it is desired to use the cable, a load is placed on the fixed carrying rope and fixed to the moving guide rope, the brake is released and the descending loads move down the cable. The brake is manipulated by one man by means of the lever *d*, figure 93, who has complete control over the descending load and can stop it whenever he wishes to by putting on the brake. The moving rope is brought to rest by the application of the brake, each time a new load is placed on the rope.

§ 100. Tightening gear for endless rope.—The wire-rope way near Brienz was the only one visited which was furnished with tightening gear. The sheave at the lower end of the wire-rope way was fixed to a wooden frame mounted on a weighted truck which moved upon a short length of rails. The truck was filled with earth and stones and was sufficiently heavy to keep the moving endless rope stretched at a constant gradient.

§ 101. Intermediate supports.—The brackets of the standards which support the two fixed ropes are similar to those used for single fixed wire ropes and have been described and figured in § 94, page 150, *et seq.*

Vertically below the fixed wire ropes on the lower beam (fig. 86, page 152) of the standard a wheel or roller is placed over which the endless guide line moves.

The guide line hangs in long loops below the fixed wire ropes between the standards, and wheels or rollers are necessary in order to prevent its fraying against the lower bar of the support or on the ground.

Figure 94 shows the arrangement over which the moving guide rope on the Pontironé wire-rope way passes.

FIG. 94.

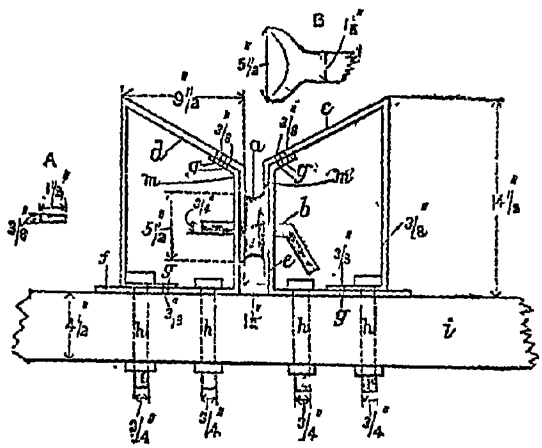


Figure 94 is an elevation of the grooved wheel and its support over which the guide rope moves. a *is the grooved wheel*, b *the pin on which it revolves. The bracket is made up of 4 strips of iron* c, d, e, f, *bolted or pinned together;* g, g, g *are pins, and* h, h *bolts. The bracket is bolted on to the lower beam* i *of the standard by 4 bolts. The section of the bar iron is shown at* A, *and the detail of the end* m, m *of the strip* c, d, *which guides the rope on to the grooved wheel is shown at* B. (*Scale 1 foot = 1 inch.*)

The V-shaped bracket made of strips of bar iron 1½ inches wide and ⅜ inch thick bolted together, as shown in figure 94 which supports the grooved wheel *a* serves to guide the endless rope on to it, and to prevent its missing the wheel and coming in contact with the lower bar of the standard.

On the Andeer wire-rope way, three grooved wheels 4¾ inches (12 centimetres) in diameter and 2 inches (5 centimetres) wide were placed on the lower beam of the standard, with the centre wheel directly below the fixed wire rope. The three wheels were very close together, so that the moving guide line could not fall between them, but must run over one or other of the three grooved wheels. The wheels rotate on a horizontal axis so as reduce the friction between them and the endless guide rope to a minimum.

§ 102. CARRIERS.—The carriers used on this system of rope way are similar to those used on simple rope ways, and a good type of carrier has been described and figured in § 95, page 154, *et seq.*

The method of fixing the carrier rigidly to the moving or guide rope, and to the way in which the load is suspended from it now generally used in Switzerland, are shown in figure 95.

FIG. 95.

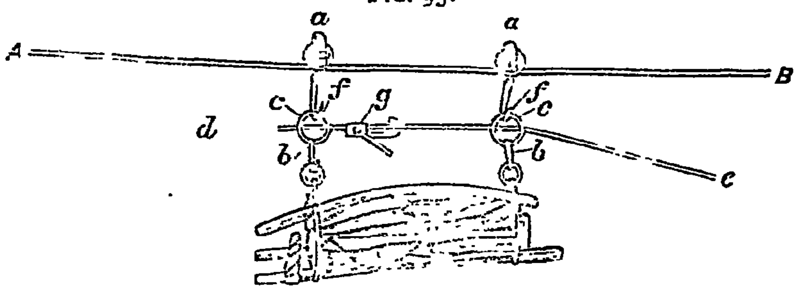
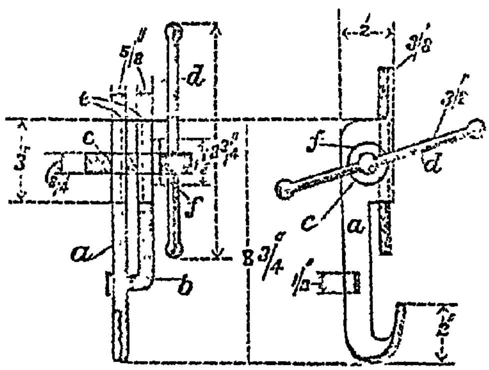


Figure 95 is a side view of a load of stone coming down the Pontironé wire-rope way; a, a *are the carriers which move down the fixed rope A B;* b *is the hook furnished with two split rings* c, c, *which are placed on the hooks* f, f, *of the carriers* a, a; d, e *is the moving guide rope gripped by the split rings* c, c. *The load is suspended from the two hooks* b, b; g *is a vice screwed tightly on to the guide rope to prevent the load from slipping along the guide line if the split rings do not grip it sufficiently tightly. (From a photograph.)*

The load in figure 95, which is stone, is suspended from two carriers *a*, *a*; it is attached by two chains or ropes to the two-eyed hooks *b*, *b*. Two split rings *c*, *c* (*i.e.* semi-circular in section) fit into the eyes of these hooks. These rings are placed one on either side of the guide rope *d*, *e* and then put on the hooks *f*, *f* of the carriers proper. The weight of the load makes the split rings clench the guide rope *f* very firmly, and the heavier the load the tighter will be the grip of the rings (*c*, *c*, fig. 95) on the guide rope. As a precaution in addition to the attachment noted above, a vice clip is sometimes attached to the guide line (*see g*, fig. 95), which serves as a stop, in case the split rings do not grip the guide line sufficiently tightly. If the split rings slip they are

brought up by the vice which is screwed tightly on to the guide line just below the upper of the two carriers. A thread is cut on the two jaws of the vice which grip the moving rope very tightly. Figures 96 and 97 show the construction of the vice grip used on the Pontironé wire-rope way.

FIGS. 96 & 97.



Figures 96 and 97 show the construction of the vice (g, fig. 95). Figure 96 is an end elevation. Figure 97 a side elevation of the vice. a, b. *are the two jaws of the vice, which are brought close together by turning the screw* c *by means of the handle* d. *A roughened groove* e, e *is cut in each jaw slightly smaller than the guide line. The guide line is gripped tightly in this groove by approaching the jaws closely towards one another. The end of one jaw is bent so as to pass through the other and enlarged so as to join them together.* f *is a washer. (Scale=⅛).*

§103. GRADIENTS ON LINE.—Very steep gradients are permissible on this system of wire-rope way, so long as sufficiently powerful brakes are fitted to two sheaves at either end of the rope-way round which the moving endless rope runs. The band brakes described in § 99, page 160, have been found to be sufficiently powerful for the wire-rope ways erected in Switzerland for the transport of timber and fuel. Each brake can be controlled easily by one man.

There is no difficulty in changing from one gradient to another as often as the configuration of the ground makes a change necessary, provided the precautions noted in § 94, page 150, are taken.

§ 104. SPANS.—The length of the spans is determined by the configuration of the ground and is commonly from 1,000 to 2,000 feet.

§ 105. A SINGLE FIXED CARRYING ROPE WITH MOVING GUIDE ROPE.—In this system the fixed rope must be supported where the descending loaded carrier and the ascending empty carrier meet, and at other places if rendered necessary by the configuration of the ground. An arrangement for allowing an empty carrier to pass a loaded one is shown in figure 98, which is taken from the late Professor Karl Gayer's Forst Benutzung, 7th edition, 1888

FIG. 98.

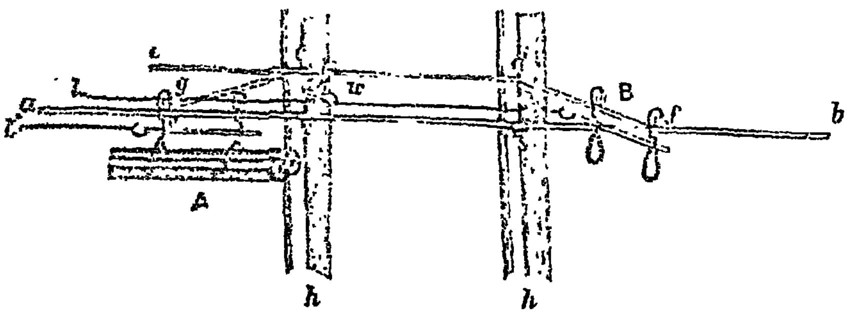


Figure 98 shows the arrangement adopted on a single fixed inclined wire rope for allowing a loaded (A) *and empty car* (B), *to pass each other. The arrangement shown in the figure is placed about half way down the slide at a small height above the fixed inclined wire rope* a b. *The passing stage* (c d) *is fixed to two stems of trees or poles* (p, p) *erected for this purpose. On reaching the point* f *the empty carrier* B *runs off on to the upper stage* d c; *the movable arm* c e *being kept raised from the fixed inclined wire rope* a b *by means of the heavy counterpoise* w; *after passing* c, *the empty carrier presses down the counterpoised arm* c e *so that it assumes the position* c g *and allows of the empty car* B *again passing on to the main fixed inclined wire. In the meantime the loaded car* A, *which reaches* f *at the same time as* B *reaches* g, *passes below the arm* c e (*which is kept raised off the main wire rope by the counterpoise* w) *and moves downwards along* a b, *while the empty car* B *moves upwards along* d c. *The loaded car* A *in virtue of its own weight, presses up the arm* f d *and passes under it, down the fixed wire rope to its lower end. As soon as the loaded carrier has passed* f, *the arm* d f *again falls on the fixed wire rope.* l, l *are the guide lines by means of which the speed of the descending load is controlled;* s s, *the supports upon which the fixed rope rests.* (*After Professor Gayer.*)

A short height[1] above the wire rope (*a b*, fig. 98) the passing stage or crossing point is attached to two stems or poles erected as supports (*c d*). On reaching this the empty car runs off on to the upper stage (*e c d f*); the movable arm (*c e*) being meanwhile kept in a raised position by the heavy counterpoise at *e*, whilst the movable arm *d f* lower down rests on the hawser at *f*. The empty car B rises on to the upper stage, on arriving at the lower end of the crossing point *f*; and on reaching *c* presses down by its own weight the counterpoised arm *c e*, so that it drops into the position shown by the dotted line *c g*; and the carrier returns to the hawser at *a*. But in the meanwhile the loaded car A—having arrived at *a* and passed below the arm *c e*, kept raised by the counterpoise at *e*, whilst B has reached *f* and begins to ascend *f d*—moves onwards in the direction *a b* (whilst B passes it overhead on *d c*) and on reaching the point *f*, raises by its own pressure the movable arm *f d*, which falls back again into its position on the wire rope each time that a wheel has passed along below it.

In this system one end of the guide line is attached to either carrier (*see* fig. 99) and passes round a wheel or drum rotating on a vertical axis at the upper end of the inclined wire rope.

[1] Dr. J. Nisbet, *OEt. Pub.*, authorised translation from Professor Gayer's Forst Benutzung.

FIG. 99.

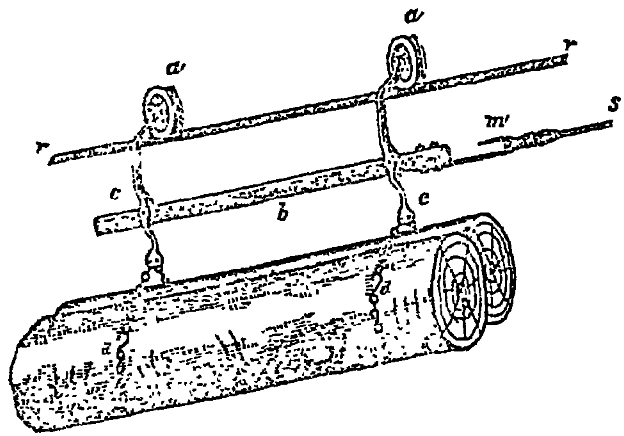


Figure 99 shows the carrier used on the Gundlischwand wire rope (Grindelwalder valley) for the transport of logs; a, a *are two flanged wheels which run on the fixed inclined wire rope* r, r. *These wheels are kept apart at a suitable distance by a rod* b. *The logs are fastened by chains* d, d *to the curved iron brackets* c, c, *which hang down from the flanged wheels. A guide rope* s *is attached to a hook* m *bolted on to the rod* b, *when the gradient of the fixed rope is steep, in order to control the speed at which the descending logs travel. (After Professor Gayer.)*

A powerful steel band brake, lined with wood, can be applied to the rim of the wheel or drum so as to make it move more slowly when required (*see* § 99, page 160, *et seq.*). The rate at which the descending load travels depends upon the speed with which the guide rope passes round the drum or wheel.

The descending load must be sufficiently heavy to pull up the empty carrier and half the guide rope. The weight which it has to draw up decreases as it descends, while its own velocity would tend to increase; but, on the other hand, the inclination of the lower portion of the wire rope is less than that of the upper portion, and this tends to decrease the velocity with which the load would trave' down.

SECTION VIII.—THE USE OF ELEPHANTS IN THE TRANSPORT OF TIMBER.

§ 106. Elephants are used in Burma, India proper, and the Andaman Islands for the extraction of large logs from the places in the forest where the trees are felled, to the nearest existing cart road or tramway, or, if these do not exist, to the banks of the nearest stream down which the logs can be *aunged* or floated. Many of the streams used for the transport of teak logs are so shallow that there is never enough water to completely float the logs, even at the highest rise. On such streams elephants are kept in readiness and push the logs down when they are stranded. This work is called *aunging*.

In Burma at present the possibility of extracting large logs depends very largely upon the practicability of procuring elephant labour. The elephants are used to drag the logs along narrow ravines and over small ridges, if necessary, as well as to push the logs down the hill-sides on which the trees grow. The favourite elephant dragging path is along a ridge.

Elephants are also extensively used, after the logs have been placed in the dry beds of the floating streams, to free logs which have become jammed in narrow portions of the beds of the streams themselves when full of water, and also to push back any logs which have become *neaped*, *i.e.* stranded on the side of the streams as they decrease in volume after the rains have ended.

The Burmese teak logs are principally exported to England in the form of squares, the lowest average dimensions of which are 23 feet long and the side of the square 12 inches. A length of 25 feet is therefore necessary to provide for the loss in cutting the drag-holes. Drag-holes are frequently cut at both ends of a log, but should never be more than 6 inches from the end. An extra drag-hole at the mid-length of a log is, as a rule, unnecessary, and should not be made unless buffaloes are used to drag the logs, when it is indispensable in the case of large logs.

When the logs are longer than this a smaller cross section is accepted, and when the cross section is larger than that noted above a shorter length is allowed.

A drag-hole (Burmese *napa*) is cut with an axe 6 inches away from the thicker end of the log, and the dragging chains of the elephant are attached to this. The log is then dragged to the nearest tributary stream that, during the rains, will contain sufficient water to allow of the timber being floated or *aunged*, or else to the nearest cart track.

§ 107. DRAGGING GEAR.—The dragging apparatus used in Upper Burma for the elephants consists of—

(1) a broad woven band, made from the soft inner bark of several species of *Sterculia* (Burmese *shaw*) not less than 9 inches broad, sometimes covered with leather to give it a smooth bearing surface; and sufficiently long for the looped end to extend some little way beyond the girth, by which the saddle is kept in position on the back of the animal. This band passes round the animal's chest, and is supported on either side just behind the fore legs, by being passed through the loops of two ropes or chains, coming down from the back of the animal.

(2) A pad, made of several layers of the inner bark of the *shaw* tree (*Sterculia sp.*), about 3 feet long and 4 feet broad is placed on the elephant's back to prevent its being chafed by the ropes or chains. Bamboo mats or layers of raw hide are often used instead of the *shaw* bark. This pad is firmly fixed in position by a rope made of *shaw* fibre or of twisted cane which passes right round the animal's body and is tightly girthed.

(3) On the bark pad, on either side of the backbone, are placed two small pieces of wood, semi-circular in section (*see* figure 100), about 18 inches long and 9 inches in circumference. These are made of any light wood.

The flat surfaces of the pieces of wood rest on the pad and the ropes pass over the notches cut to receive them. These pieces of wood are hollowed out as much as possible to make them light.

The loops which support the breast band, as well as the girth, pass over these pieces of wood.

FIG. 100.

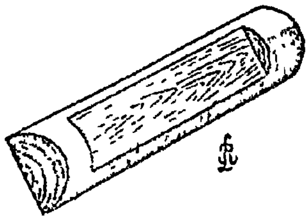


Figure 100 represents one of the two pieces of wood placed on the top of the pad, on either side of the backbone of the elephant, to prevent the chains or ropes from rubbing the animal's back. (Drawn by Mr. R. Lowis)

In Lower Burma a light wooden saddle (figure 01), is commonly used instead of the two pieces of wood just described in order to prevent the elephant's back from being rubbed.

The side pieces are 2 feet 5 inches long with a section of about 3 inches square, while the ties are 1 foot 9 inches long and about 2 inches square, so that the saddle-tree is 1 foot 9 inches high and 1 foot 9 inches long.

FIG. 101.

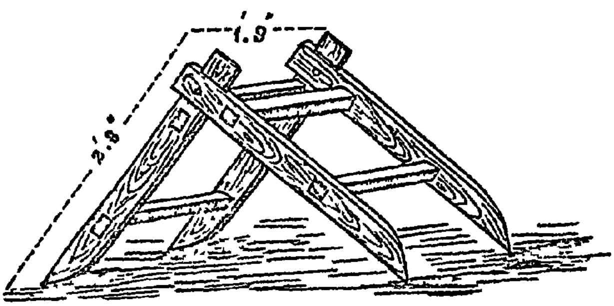


Figure 101 shows a saddle which is sometimes used instead of the two pieces of wood, one of which is shown in figure 100, to prevent the chains from rubbing the elephant's back.

This type of saddle is much heavier than the pieces of wood described above, and, where the forest is dense, is very liable to catch in the overhanging branches of trees.

The dragging chains are of unequal length, the shorter of the chains has a hook at one end and a ring at the other. The longer chain has a hook at either end. One hook of each chain is placed in one of the loops in which the breast band ends. The longer of the two chains is then passed through the drag-hole and hooked on to the ring of the other dragging chain, the junction of the two chains is in this case some distance from the drag-hole cut in the log. The dragging chains used in the Shweli forests, Katha Division, Upper Burma, are made of steel and are of different lengths, the longer chain is usually from 11 to 17 feet, and the shorter one from 9 to 15 feet long. The mahouts usually have connecting links with them, so that in case of a breakage, the chain can be immediately repaired.

Figure 102 shows an elephant dragging a log.

The whole of the dragging gear described above is rough but efficacious; is cheap but easily repaired, and the elephants very rarely get rubbed. With the exception of the chains, the whole of the gear is made up and kept in repair by the mahout (elephant keeper), who himself collects the materials of which it is made. Elephants are chiefly used in the hilly portions of the forests in Upper Burma. Buffaloes are beginning to be used in the more level stretches of country which succeed the hilly portion. Two or three pairs of buffaloes are harnessed to each log in order to draw it to the floating stream. Two pairs of buffaloes are said to be equal to one elephant.

Sometimes two elephants are harnessed to one log, while a third pushes behind. In dragging by elephants care should be taken to tell off the biggest and strongest elephant to the heaviest log, and to see that the dragging paths are chosen over the best and most level ground, as mahouts are apt to take short cuts without considering gradients. Mahouts should be told when dragging timber not to keep their elephants moving continuously, but to give the animal repeated rests for a few minutes at a time especially over rough ground. In the Andaman Islands a ton of timber dragged a distance of 1½ miles is considered to be a good day's work for one elephant.

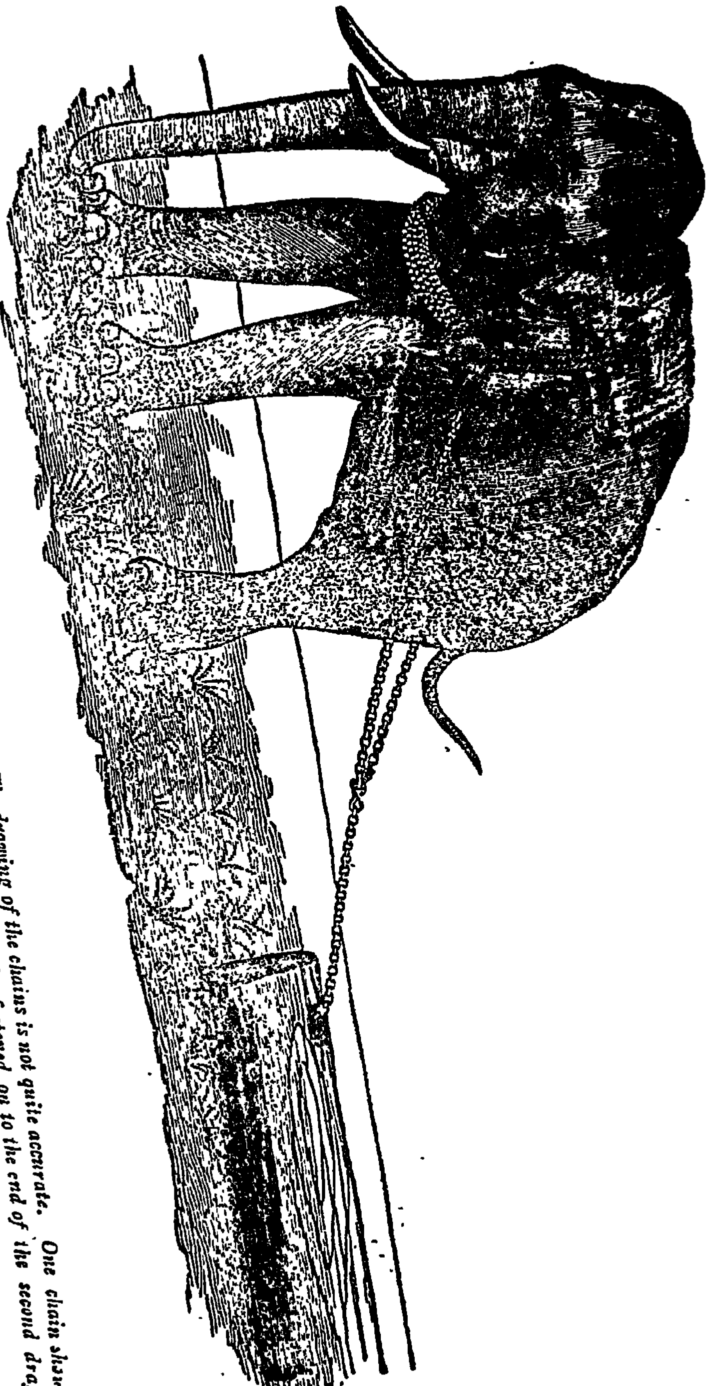


Figure 102 shows a good type of dragging elephant harnessed to a log. The drawing of the chains is not quite accurate. One chain should go from the loop of the breast band direct to the drag-hole cut in the log, pass through it and be fastened on to the end of the second dragging chain. The point of junction of the two dragging chains is too far away from the end of the log. (From a photograph).

Great care should be taken that elephants are not overworked. An elephant in good health can work six hours a day without[1] injury.

§ 108. The dragging apparatus used for the buffalo is of the simplest nature, and consists of a stout yoke to which the dragging chains are attached. This yoke is very heavy and clumsy, being as much as one man can lift comfortably. Where three pairs of buffaloes are used, it is customary to fix a screw bolt 5 inches long, furnished with a ring 4½ inches in diameter, into the centre of the log, and to attach dragging chains to this as well as to either end. One pair of buffaloes is attached to it and the other two pairs are yoked, one to each of the drag-holes. The Burmese often attach a team of five to ten pairs of buffaloes, one in front of the other to one log of large size, but this is a great waste of power, as it is impossible to get the animals to drag all together. The screw bolts are used again and again. They have proved unserviceable for elephants, as in dragging they jerk a good deal and tear the bolts out.

§ 109. In Burma, elephants are used to push logs along, and in this case their heads should be protected with well-stuffed leather pads. They are never made to drag logs down steep slopes.

Elephants use their tusks for turning over logs or lifting heavy weights.

In a fairly level forest, average sized elephants can drag logs of 60 to 65 cubic feet each; or two or more elephants can be made to drag one big log. Buffalo dragging can be resorted to with great advantage, while in the dry season elephant and buffalo carts can be used where the country is fairly flat.

In Madras, when the ground is soft, during the rains, where logs have to be dragged up slopes, round poles of soft green wood are laid across the roads, sufficiently embedded in the soil to maintain their position by the weight of the logs passing over them.

In hilly forests, where the timber has to be dragged up several more or less steep inclines, and to be rolled down places too steep for dragging, the work is very trying, even for the

[1] Elephants and their treatment in health and disease, by Mr. W J. Slym, late Deputy Conservator of Forests.

strongest elephants. In fact in such places small elephants can do little work, as it is impracticable to make several elephants drag one log up a steep and narrow dragging path, as they seldom pull together and the strongest of them does all the work. In Burma only tuskers are used to work logs down steep hill-sides, and it is very tedious work; the logs when rolled or pushed down are caught on the way by bamboos or trees, and the tusker has to follow them and start them again, finding a footing with difficulty. When dragging heavy logs in hilly forests, elephants are very liable to hurt their feet; the cuts and sores fester badly and often incapacitate the animal from work for months.[1] In such places the German krempe (see page 183) might be used with advantage.

§ 110. The following information, regarding the expenditure involved in the purchase and maintenance of elephants in Burma, is of interest:

The average dragging elephant in Burma costs R1,800, and the life of an elephant at timber work averages 15 years, consequently the capital involved (allowing interest at 5 per cent.) to purchase an elephant and replace it every 15 years is $\frac{1800 \times (1 \cdot 05)^{15}}{(1 \cdot 05)^{15} - 1}$ = R3,468, and the annual cost is R173. Attendants cost R26 a month or R312 per annum; the cost of medicines, repairs to gear and other incidental expenses may be put down at R25 per annum; the annual work of an elephant costs therefore R510. An elephant can drag, and arrange in beds of streams ready for drifting, 140 tons in a year in a fairly difficult forest, and the cost of dragging and *aunging* in such a forest is R3-10 per ton. For dragging alone, the cost is probably less than R1 per ton. The outturn given is about the average of the actuals of the Swa forest for 4 years.[2]

§ 111. In Coorg[3] it was the custom to make the elephants hold the ropes, attached to the logs to be dragged, between their teeth. The same custom is found in South Kanara and Malabar

[1] The "*Indian Forester*," Vol. XXI, page 188.

[2] Mr. P. J. Carter, late Conservator of Forsts, Burma, in the "*Indian Forester*" May for 1895.

[3] The late Mr. G. H. Forster in the "*Indian Forester*" for September 1892, page 332.

and is probably the universal native practice in the peninsula of India proper. The ropes used are made of the inner bark of trees. Coir or hemp ropes are never used, as the fibre gets into the interstices of the teeth, but the bark rope, being made of ribbons of the inner bark only, does not appear to get into the teeth, or to cause the elephant any inconvenience. The ropes are from 6 to 9 feet long and 3 to 4 inches in diameter at one end, gradually tapering off to the thickness of a piece of stout cord at the other. The thin end is passed through the drag-hole in the log and the rope pulled through sufficiently to allow of its being tied. When dragging the log the elephant takes the rope between its side teeth and drags with its mouth, consequently the fore end of the log is generally along side the elephant's fore leg and its hind legs are usually 2 or 3 feet from the log. The reason for adopting this system is that in dragging logs down a slope, if the log takes a run and gains impetus the elephant can instantly let go its hold on the ropes and away goes the log by itself: if the elephant were fastened to a log moving down a steep slope, the log might, if it gained sufficient impetus, drag the elephant with it and serious, if not fatal, accidents might result to both elephant and mahout.

The late Mr. Rhodes Morgan, Deputy Conservator of Forests, Madras Presidency, a great authority on elephants and their treatment in captivity, says elephants which are made to drag timber with their teeth never live long. The teeth are loosened, chipped or pulled out, alveolar abscesses continually form, the teeth become carious and the elephant suffers fearful agonies. Tuskers become exceedingly dangerous when thus afflicted and will kill their keepers. When the elephants have thus lost or damaged their teeth they can no longer properly chew or digest their food, they fall off in condition and eventually languish and die.

§ 112. The following information with regard to the treatment of elephants has been contributed by Mr. C. G. D. Fordyce, Deputy Conservator of Forests :—

"It is well known from experience that mahouts are not to be trusted unless they find that their officer knows, or has obtained some knowledge of, how their charges are to be treated.

If possible, elephants should not be worked every day of the week, especially in very hot weather, and where no shade or water is available.

For baggage elephants, 8 hours' marching a day is a good day's work. For elephants dragging timber, 6 hours' work a day is sufficient. When working, elephants should start in the early hours of the morning so as to finish their work before the heat of the day.

No mahout should be allowed to work an elephant without stirrups, which consist usually of a rope round the neck dividing into numerous strands underneath. It is necessary to use the stirrups when it is required to restrain the animal, as otherwise the mahout is apt to be thrown and occasionally trampled on and killed by the elephant. A mahout, when working an elephant, should always sit on its neck and use his stirrups, as by so doing he has a proper control over the animal.

Mahouts often give their elephants sore backs on purpose, so as to have an easy time themselves while the elephant is laid up, and the only means of checking this, if such a case is suspected, is to put the mahout on half pay, or to get rid of him.

The best of elephants, constantly employed on dragging timber, have to be very carefully looked to. The feet should be regularly cleaned after each day's work, and the elephants put on the sick list directly any symptoms of sore feet are visible.

Elephants should, with few exceptions, be bathed every day, not immediately after work, but when they have cooled down; they should then be well rubbed with pumice stone and thoroughly washed.

When an elephant comes in from work, the small pad (gâddâh) should not be taken off at once, but should remain on for some time.

Except in Burma, Government elephants are seldom let loose in the jungle to pick up their food at night, although it is almost invariably done by natives who own elephants. Elephants let loose in this way, where there is ample fodder, always keep in better condition, owing to the variety of food and the quantity obtainable. When let loose in the jungle elephants should be hobbled, in some cases both hind and fore legs. Amongst natives and in the Andamans, cane hobbles are used, whilst with Government elephants in India, iron chains are used for this purpose.

After an elephant has been brought in from its work and has cooled down, it should be taken away to the forest *immediately* to collect its fodder and graze, or should be hobbled and turned loose *at once* to feed. It must be remembered that elephants in a state of nature, are always on the feed when not asleep, and they only sleep for about 5 hours in the 24.

When elephants have their fodder brought in for them and are tied up at night, it is most important to see that the fodder is ample and of the right kind; if they are stabled repeatedly on the same spot, that the grasscuts clear away the litter and refuse every day, and that the place is kept clean and sweet. Good drainage has a good deal to do with this. Mahouts are very careless about this, and also about the quantity of fodder they bring in; it must be remembered that if fodder is

constantly insufficiently supplied, elephants will not keep in good condition; if worked hard at the same time, they are particularly liable to become anæmic and dropsical, and no amount of paddy or chappati rations will compensate for the short weight of green fodder supplied.

Generally, elephants are supplied with paddy[1] or chappati[2] (in Northern India) rations. Mr. Sanderson states that paddy rations are not necessary if sufficient green fodder is supplied; but I would always advocate paddy being given, to the extent of 40 lbs. (the amount depends upon the size of the elephant and the work it does) a day, to elephants that have really hard work; and in other cases, although not necessary, it is advisable to give 5 or 10 lbs. daily, half in the morning and the remainder in the evening, as elephants let loose in the jungle to pick up their own fodder there, then acquire the habit of looking forward to their rations and are not so liable to stray. It should be insisted that paddy, when given, should be made up into bundles with grass or plantain leaves, with a pinch of salt in each bundle, and the grasscut should make these bundles and then feed the elephant with them himself. Mahouts always try to avoid doing this, as it gives them a little trouble, and the only alternative is for the elephant to blow the loose grain or paddy down its throat, in which case a great part of it is lost, and large wastage arises through the paddy passing out undigested. This method of feeding is also liable to set up irritation of the stomach, and is apt to lead to colic.

Elephants should be supplied with salt and tamarind rations,—salt according to the size of the elephant up to a chittack a day, and tamarind up to half a pound or so; a small quantity of mustard oil (for big elephants 1 chittack a day) should be supplied and care taken that the mahouts apply it to their elephants' heads.

Elephants when suffering from worms, or other stomach ailments, eat earth, which sets up purging, and during such times paddy rations should be stopped and great care taken about bathing so that the elephant does not get a chill.

There is no necessity to go into the question of medicines and the various ailments of elephants, but the simpler the medicines the better.

In case of festering sores or wounds, mahouts should not be allowed to probe them with their dirty fingers as they like to do. In these cases it is well to insist on a syringe being used, and the festering sore or wound being kept scrupulously clean and disinfected with such common antiseptics as dilute carbolic acid or Condy's fluid. In open sores, blue stone can be used as a caustic."

§ 113. There is a large waste of timber caused by making a drag-hole near each end of the log; because, when measuring up the logs for the payment of duty, only one drag-hole is included in the length; because, since the second drag-

[1] Uncooked unhusked rice.
[2] Large thick cakes made of ground corn and water, and roughly baked.

hole is made at the smaller end of the log, it necessitates cutting of 1 or 2 feet off the smaller end of the log when it is required to saw the largest possible square out of it. Thus 1 or 2 feet at one end of the log is absolutely lost. If the drag-hole is made near the larger end of the log, that end is usually so much larger than the smaller end that when the square is cut out of the log, no trace of the drag-hole is visible on the teak square. As far as our experience goes at present, one drag-hole cannot be avoided, as an elephant will jerk out any screw bolt which has yet been tried, but the drag-hole at the smaller end of the log is totally unnecessary, as it is only used for fastening the logs together when they are made into rafts, and some other method of fastening the logs together could easily be introduced.

Formerly, in Bengal[1], no drag-holes were made in the logs which were extracted by means of elephants. The dragging chains were each passed twice round the thick end of the log and the hook of one chain passed through the eye in which the other ends. When the elephant began to drag the log the chains were pulled tight and did not slip off the log.

In the Andamans also, drag-holes have been given up, the dragging chains have been made longer, and simply passed round the large end of the log. In the case of logs, which from their weight, or other causes, it is desirable to rough square at the site of felling, it is found advantageous to have a small portion of the log unsquared, to give the chain a tighter grip while any friction between the chain and the ground is thus avoided.[2]

SECTION IX.—MECHANICAL CONTRIVANCES.

§ 114. The following method of moving large logs down steep hill-sides is extensively used in the German Swiss forests and seems to be peculiarly suitable for moving logs down steep hill-sides in India:

[1] Mr. J. S. Gamble, Conservator of Forests, retired.
[2] Mr. C. G. D. Fordyce, Conservator of Forests.

All that is required[1] is a long piece of strong rope, 164 feet (50 metres) long, one end of which is furnished with a loop, a strong iron hook with a ring attached (figure 104, page 184) and an instrument (figure 103) shaped something like a pick-axe, but with only one arm (German *krempe*), about 18

FIG 103.

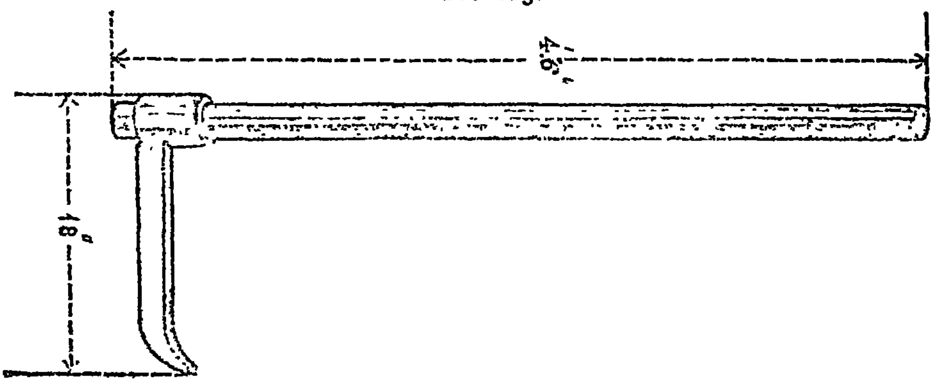


Figure 103 is a German krempe used for moving logs down a steep slope. (Scale 1 foot = 1 inch.)

inches long, 1½ inches deep and ⅝ of an inch wide and slightly curved at the end only. The socket into which the handle fits is 3 inches long. The krempe is fitted with a wooden handle about 4½ feet long.

The logs are not barked until they are to be moved down the hill-side. A deep triangular notch is made with an axe near the large end of the log and the hook is driven firmly into it. The looped end of the rope is placed through the ring, with which the hook is furnished, and kept in position by placing a bent piece of wood through it (*see* figure 104).

The rope is then passed two or three times round a conveniently situated tree. The larger the log to be moved, the greater is the number of turns passed round the stem of the tree. Five or six men under the direction of a leader, who

[1] Journal of a tour made in the continental forests of Europe in 1893, by Mr. J. Copeland, Deputy Conservator of Forests, Burma.

FIG. 104.

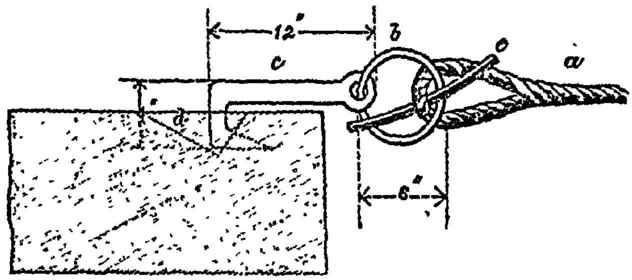


Figure 104 shows how the rope a *is attached to the ring* b *of the hook* c, *and how this latter is fixed into the log itself;* d *is a triangular notch cut in the log with an axe to receive the hook,* e *is a piece of tough wood which keeps the loop from slipping through the ring. (Scale 1 foot = 1 inch.)*

stands near the top, *i.e.* forward end of the log, and direct its course, work the log down by means of krempes. A man and a boy hold the end of the rope which has been passed round the tree and pay it out slowly so as to allow the log to move gently down the hill-side. The points of the krempe are driven into the log on either side, so that the lower end of the handle rests on the ground, and by giving them a lift and downward twist motion the log is moved gradually down the hill-side.

If it is desired to stop the log, the man and boy who hold the end of the rope put a strain on it; and if necessary, the men provided with the krempes drive them into the log and help to arrest its progress. The man who is in charge of the end of the rope wound round the tree, can stop the log at any moment he likes, by catching hold of the rope firmly, just above the point it goes round the tree and putting his whole weight on the rope. By doing this he tightens the turns of the rope which are round the tree and thus stops the motion of the descending log. When the rope has nearly run out, the log is prevented from sipping down by driving the krempes into it and holding

it up, while the rope is removed from the tree round which it was first wound and placed round a tree close to the log.

The direction of the log is easily changed by means of the krempes, and the log thus guided down the slope in any required direction.

Logs can be taken down slopes, the gradient of which is more than 1 in 5 or 11¼ degrees, by means of krempes and a piece of rope.

Logs are moved down slopes which have a gradient varying from 30 degrees on the upper portions to 45 degrees on the lower parts by means of a rope and 5 or 6 men furnished with krempes.

SECTION X.—TRANSPORT BY WATER.

§ 115. Logs, scantlings and firewood may be transported by the agency of water—

(1) by floating,

(2) by rafting,

(3) as a cargo in ships or boats.

Timber and firewood are allowed to float down narrow streams which contain but little water or are so full of obstructions that only single logs or scantlings can find their way down.

The pieces of timber or firewood are thrown singly into the stream and are allowed to find their own way down it. Floated timber is not directly under the control of men during its actual passage down the river.

Floating is only resorted to in those streams which are unsuitable for rafting, and as soon as a stream becomes sufficiently large, deep and free from obstacles to allow of the passage of a raft down it, and provided the current will allow of rafts being taken down the stream, the floating timber is caught and made up into rafts. Rafts are made up of a number of logs, scantlings or pieces of firewood fastened firmly together and taken down streams by men, who live on the raft and guide it down the stream.

Teak-and padouk-squares are carried to England and other places in ships as ordinary cargo. Boats are largely used in Rangoon and the Sundarbans for the carriage of timber and firewood to market; while firewood is carried along canals in the Madras Presidency and elsewhere.

§ 116. CONDITIONS NECESSARY FOR FLOATING.—All streams are not naturally suitable for the purpose of floating timber. In order that logs or scantlings can be drifted down a stream it is necessary that—

(1) the stream should flow in the direction of the market;

(2) the water should be sufficiently deep to allow of the timber floating without touching the bed of the stream;

(3) the bed of the stream should be fairly free from natural obstructions, such as bad rapids, sub-merged rocks and back-waters;

(4) the stream should be sufficiently wide to allow of the logs turning completely round.

It will be found a great advantage if the current is moderately strong, not too swift nor too slow; in the former case the timber would be considerably damaged during its progress down the stream, and in the latter the logs would move very slowly down the stream and would be liable to form a block across it.

§ 117. In India at present no special methods have been introduced with a view to increasing the ordinary volume of water in a stream, so as to utilise it for floating firewood or scantlings as used to be done in Europe.

The construction of expensive works in order to allow the utilization of small streams for the transport of fuel has now generally been abandoned on the continent of Europe in favour of the construction of cart roads or sledge roads, which can be used for general in addition to forest transport.

In Europe, however, streams which, in their natural condition, had not a sufficient volume of water to allow of their being used for the transport of firewood and scantlings, were

formerly rendered suitable for the drifting of these materials by the construction of dams either of masonry or of wood and stone across the bed of the stream so as to form a reservoir of water, which could be allowed to escape and so to increase the ordinary flow of the stream sufficiently to carry the firewood or small scantlings as far as the large stream into which the small one flowed. When the small stream was not required for floating purposes, the water was allowed to flow through a sluice constructed for this purpose in the dam, on a level with the bed of the stream. The dam was made sufficiently strong to support the pressure of the water in the reservoir, and safety sluices were usually made near the top of the dam to allow the water to overflow when it rose too high.

The lower sluice was closed by a specially constructed door when the reservoir was to be filled. The firewood to be transported was piled up in the bed of the stream immediately below the dam, and when a sufficient volume of water had collected behind the dam the sluice gate was opened and the water allowed to escape, carrying the firewood with it.

The construction of dams, in order to allow of small streams to be used for drifting purposes, has been given up in the Baden Scharzwald[1] in favour of transport along cart roads for the last twenty years. But in the Salzkammergut District of Styria such dams were still used in 1887 for the transport of fuel, but no new ones were being made.

§ 118. If the course of a stream is in parts very circuitous and the current slow, its velocity may be increased by straightening its course by cutting a new channel for it. In India this is rarely done on account of the expense involved in making the new channel. The best fall in a stream for floating purposes, so far as is at present known, varies from ½ to 1½ in 100 or from 26 to 79 feet in a mile. This is, however, not of much importance, as the streams which exist have to be used practically as they are found, or with such preparation as is described below.

[1] Journal of a tour in the continental forests of Europe in 1893, by Mr. J. Copeland, Deputy Conservator of Forests, Burma.

In the Cuddalore Range,[1] Madras Presidency, a canal 704 yards long, 10 feet wide at the base, 29 feet wide at the top and with an average depth of 5 feet was dug at a cost of R800 to avoid a mile of water-way, and a saving of at least 4 annas a ton was effected in the cost of transport.

§ 119. PREPARATION OF A STREAM FOR FLOATING.—The chief obstructions to floating met with in streams are—

(1) *Rapids, i.e.* portions of the river where the fall is great, the river studded with projecting rocks, and where it is also often shallow.

(2) *Projecting rocks.*—These are usually associated with rapids, but not necessarily so.

(3) *Sunken rocks and stranded or sunken trees.*

(4) *Back-waters.*—These consist of back eddies of slack water which occur more or less frequently by the side of the main current, more especially where the bed of the stream narrows into a gorge. They also form behind masses of rock which project out into the river bed.

The logs and scantlings leave the main current (being often sucked into these back-waters) and move round and round in the back-waters instead of proceeding down the stream. When the back-waters are completely filled with pieces of timber, the drifting wood strikes against the pieces of timber imprisoned in it and is deflected again into the main current.

(5) *Branches of the stream other than the principal one.*

(6) *Sharp bends causing obstructions or over-reducing the velocity of the stream.*

Treatment of rapids.—So long as there is sufficient water to take the logs or scantlings over the rapid, nothing need be done. Where, however, the logs are caught on projecting rocks, these rocks must be removed by blasting, and a clear passage prepared, down which the logs can float.

Where the bed of the stream is broad, it may be found more economical to prepare a special channel by the side of the

[1] Colonel Campbell-Walker, I.S.C., Conservator of Forests, retired.

rapid down which the logs can be floated, thus avoiding it altogether. Where this is done steps must be taken to guide the logs into the entrance of the channel. The mouth of the channel should be made sufficiently far up-stream to prevent the logs being drawn into the rapid. A line of logs moored slantwise across the stream will usually be found sufficient to turn the logs into the prepared channel.

Projecting and sunken rocks as well as sunken and stranded trees should be removed by blasting with dynamite or good blasting powder. Dynamite can be used under water.

Back-waters and side branches of streams can be closed by mooring a line of logs across the entrances to them. The line of logs should be securely fastened to two posts well embedded in the ground at either side of the entrance to the back-water (*see* fig. 105) or the side channel. The drifting logs will be carried by the current against this line of logs and will be deflected again back into the main stream.

FIG. 105.

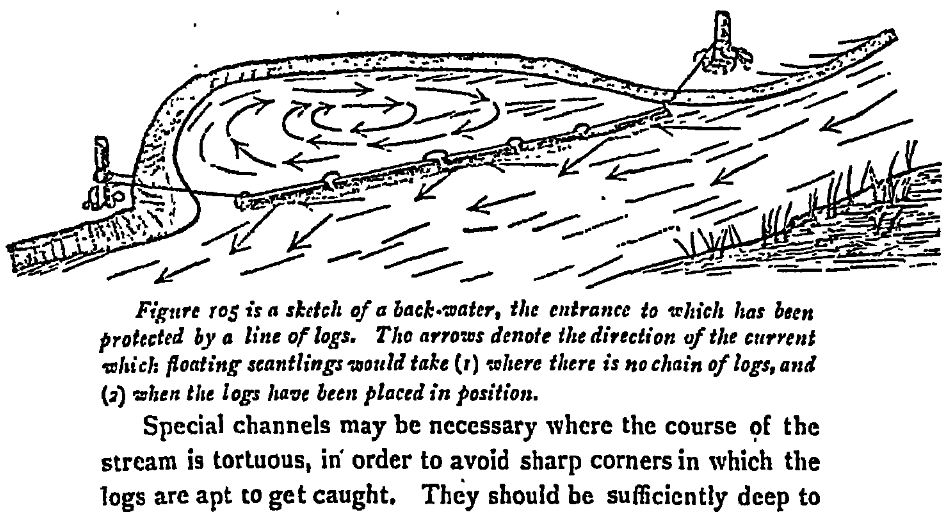


Figure 105 is a sketch of a back-water, the entrance to which has been protected by a line of logs. The arrows denote the direction of the current which floating scantlings would take (1) where there is no chain of logs, and (2) when the logs have been placed in position.

Special channels may be necessary where the course of the stream is tortuous, in order to avoid sharp corners in which the logs are apt to get caught. They should be sufficiently deep to allow of the logs passing through them easily, but if they are short and efficiently patrolled, they need not be so broad as the logs or scantlings are long.

Where logs or scantlings are floated for long distances, the preparation of the river bed and the removal of obstacles has to be done gradually as funds are available. The worst obstructions should be removed first, and when these have been satisfactorily dealt with, then the less important obstacles should be attended to.

Gangs of men in India, and trained elephants in Burma, are employed in patrolling the worst parts of the floating streams when timber is coming down, in order to break up such blocks as may be formed and to free such logs and scantlings as may have been caught. After all the logs or scantlings have been launched, a gang of men proceeds down the stream, accompanied by elephants, where practicable, in order to free all the logs and scantlings which have been caught in rapids, jammed between rocks, or have found their way into back-waters, and to ensure that the launched timber reaches the station where it is collected and made up into rafts.

§ 120. FLOATING TEAK LOGS IN BURMA.[1]—"The general preparation of the streams is the same as elsewhere. The worst obstructions in the shape of rocks are removed by blasting, dynamite being used in preference to blasting-powder. The streams are also kept free of fallen trees. If the streams are very tortuous, sharp bends are often cut through with narrow channels, which are soon widened when the stream flows through them. The preparation of the river beds is done in the dry weather when the streams are at their lowest. Some of the streams used for drifting are very shallow and there is never enough water in them to float logs for any considerable distance, and in this case the logs have to be pushed along by elephants (*aunged*) nearly to the rafting streams. In the important Tharrawaddy Division there is one obstacle to contend with, which is not met with in other divisions. The timber worked out from this division is extracted by the various tributaries on the left bank of the Hlaing, or Rangoon river; this river runs parallel to the Irrawaddy and at a distance of about 12 miles from it. When the Irrawaddy is in high flood it frequently overflows its banks. Its level is higher than that of the Hlaing, the whole country between the two rivers becomes one vast sheet of water, and the result is that the months of the timber-floating streams silt up, often to the level of the surrounding country; and the water coming down them spreads in a sheet over the land, often carrying logs with it. These have to be dragged for long distances before they can again be launched in sufficient water to float them, and many logs get lost in the *kaing* grass and are burnt the next dry season. Canals are often cut

[1] The late Mr. G. Q. Corbett, Deputy Conservator of Forests, Burma.

through the large sand banks thus formed along the nearest route to the Hlaing, for if this were not done there would be no knowing what route the water would take the next year. The keeping open of these canals requires constant supervision, and care must be taken that no block of timber occurs anywhere throughout their length—a block for a single day would cause them to silt up again, and the channel would have to be entirely re-made.

Elephants are always kept on these channels, and the logs as they come down are generally dragged up so as to line the banks above the entrance of the canal and are launched a few at a time, an elephant accompanying each batch as it goes through the canal. The lining of the banks with logs has of course the further advantage of keeping the water from overflowing. In many of these streams, when they reach the plains, the level of the stream is above that of the surrounding country, and if they are not carefully watched there is every probability of their bursting through their banks and of the timber being carried away into the surrounding fields or jungle. If such a breach occurs it must be stopped with as little delay as possible. The best way to do this is to plant strong posts fairly close together, lace a net-work of split bamboo between them and to fill up the interstices with *taungya* refuse—which comes down the streams in immense quantities. Silt is soon deposited against this section and a new bank is formed.

Serious obstructions are often caused by the logs jamming in a stream in consequence of too many having been launched at one time. I once had a block of over 1,000 logs in a stream with steep banks which it took me twelve days to remove. The logs had to be pulled from the back of the obstruction up-stream, one by one, and fastened to the banks until they could be again launched.

When a certain number had been thus removed, the rest were so inextricably jammed that not a log could be moved. Dynamite was then employed as follows:—A charge with a long fuse was put into the end of a long bamboo, which was driven down between the logs into the sand at the bottom of the stream and then exploded. Each explosion loosened a few logs which could then be treated as the other loose logs were. The dynamite injured a few logs, but not very many, and as the removal of the obstruction was very urgent, the damage was quite justifiable.

In the Shweli forests of the Katha Division, Upper Burma,[1] the teak logs are felled, and dragged into the bed of any stream that in the rainy season may have sufficient water to float the timber into the main rafting stream. This may occur any time between July and October. When the streams begin to rise all the elephants are at once turned out to patrol the stream and to assist in breaking up any jams that may occur, often the freshet only lasts six hours, and a single tree falling across the stream or a log jamming in an awkward corner will prevent any timber floating out during the short time that the stream is sufficiently high to allow of its so doing. This

[1] Mr. E. A. O'Bryen, Deputy Conservator of Forests, retired.

patrolling is dangerous work for the elephants, as they are liable to be injured by the logs coming down, and are occasionally drowned by losing their footing and being carried away under a jam of logs."

§ 121[1]. FLOATING SLEEPERS IN THE NORTH-WESTERN PROVINCES.—"Sleepers and scantlings are extensively floated down the Tons, Jumna, and other rivers in the North-Western Provinces, both by Government agency and by private contractors.

The sleepers extracted departmentally in the Jaunsar Forest Division (North-Western Provinces) are launched as soon as the rains are over, and the river has gone down sufficiently to allow of the sleepers reaching their destination in safety.

The season for launching Government sleepers is from November to February, while private contractors launch scantlings as late as the beginning of June.

The sleepers float down as far as Dakhpathar, about half a mile below the point where the Tons runs into the Jumna. The distance from Bamsu where the sleepers are now being launched to Dakhpathar is 68 miles, and the average time occupied by the sleepers to travel that distance is two months. The river is fairly free from obstructions to the floating of scantlings up to 12 to 15 feet in length, and the percentage of losses is very small. On the Government sleepers the loss in floating is on an average only 2 per cent.

After the whole of the Government sleepers have been launched, a gang of *mallahs* (*see* page 209) are sent down the river to free all the sleepers that have stranded on the banks, stuck on rocks in the middle of the stream, or have found their way into back-waters. The gang numbers from 35 to 37 men, including three pairs of *darai* men (who move about the stream on inflated bullocks' skins) and 16 or 18 *tarus* (men provided with goat skins to help them in swimming). The *darai* men work in the back-waters, and carry men and baggage backwards and forwards across the river as required, and also work in the smoother reaches. The *tarus* disengage sleepers from rocks and do all the dangerous work when the river is rapid, while the coolies, who make up the party, carry the loads of the whole party in addition to their river work. Two or three forest guards accompany the gang."

§ 122. FLOATING ON THE PUNJAB RIVERS[2].—"The following are the rivers that are chiefly used for floating. The Ravi, which flows by Lahore; the Jhelum, which skirts the Hazara District; the Chenab, which passes through Pangi; the Beás, which traverses the Kulu District; and the Sutlej, which is the chief line of export for the Bashahr forests.

Formerly logs were almost exclusively launched, as the extraction required a much smaller outlay and less control, but in the case of the Ravi and the Beás the extraction of logs has been almost entirely given up and the con-

[1] Report on transport of sleepers by water from the hill forests to Dakhpathar, 1886, by Mr. A. G. Hobart-Hampden, Deputy Conservator of Forests.
[2] Mr. A. L. McIntyre, Deputy Conservator of Forests.

version of the trees in the forests into sleepers and scantlings is now the rule as it has been found that these rivers are not suitable for floating large logs. They are much obstructed by rocks and rapids, and consequently the logs take a very long time to reach the market, and a large proportion (on the Ravi 30 per cent.) never reach their destination. Again, all the trees near the river and their tributaries have been felled, and it is more economical to convert the trees in the forest than to move the large logs to the drifting stream now that the market for large logs has disappeared.

The Ravi river has been used for floating logs since 1864. The logs were chiefly launched into its tributaries and found their way down them into the main stream. Nearly every ravine, on the slopes of which deodar is found, has been used at one time or other; logs up to 10 to 15 feet in circumference and 60 feet long being often extracted. As the number of exploitable trees near enough to large ravines to be launched into them decreased, the custom of converting the logs into sleepers and scantlings gradually came in, and now all the outturn of the forests is converted locally into scantlings.

Logs, which were launched directly into the main stream of the Ravi took from four to six years to reach the plains depôts, and some of the small tributaries still contain logs launched twenty or thirty years ago Deodar is extracted almost exclusively, as it has been found that kail (*Pinus excelsa*) and rai (*Picea Morinda*) in the log are unable to stand long exposure like deodar, and reach the plains depôts in a very bad condition. On the Sutlej and the Chenab, floating in the log answers better than the floating of scantlings and sleepers. Both these rivers are free from obstructions and are larger than the Ravi, so that even large logs reach the plains depôts in one or two years. In the Chenab and Sutlej the difficulty of patrolling the banks where they pass through Native States, and the presence of violent rapids, in which the sleepers get broken, are against the floating of converted timber in these rivers, and as a large proportion of trees grow close to the banks of the main streams, log floating is considered to be better than the floating of scantlings; and in consequence the greater part of the timber is still extracted in the log."

§ 123. SEASON FOR FLOATING TIMBER.—The best season of the year for floating timber depends upon the nature of the stream or river used for that purpose, its situation, and the rainfall of the district. In the case of small mountain torrents often the only time of the year that it is possible to use them for floating purposes is in the middle of the rainy reason; as at other times of the year the quantity of water in them is insufficient to allow of timber or firewood being floated down them. When such streams are used for the transport of timber, the scantlings or logs to be floated must be caught just above the several junctions of the small tributaries with the main stream

and stacked on the banks of the large river until the rainy season is over and it can be used for drifting purposes.

In the case of large streams, subject to heavy floods during the rainy season, which contain sufficient water in the cold weather for floating purposes, the logs or converted timber should be launched after the rainy season, as soon as the river has fallen to its normal condition. If the logs are launched too soon, many of them will be left high and dry as the river falls and will have to be pushed into the river again.

In many cases the floating season is dependent on the rafting season on the larger rivers into which the streams suitable for floating flow, as the timber must reach these in time to allow of their being rafted down to the market, while the river is suitable for this purpose.

In Upper Burma the teak logs are worked out of the forest in the hot weather and placed in the beds of such small streams as intersect the forests which usually contain some water during some part of the rainy season. Those stream beds are chosen which, although dry during the greater part of the year, contain sufficient water after a heavy burst of rain in the monsoon to allow of the logs being *aunged* or floated down to the mouth of streams which contain water at all seasons of the year. By making use of such streams the cost of transporting the log is materially decreased, but on the other hand if the rains are short, the logs may stay in the beds of the streams for a whole year longer than was anticipated.

Scantlings and logs to be floated should be launched when the river is falling, as they are then carried without hindrance to their destination; when a stream is falling, the water in it is lowest in the middle, and floating objects incline towards the centre, while if the timber or firewood is thrown in when the stream is rising, the water in the middle of the stream is highest and tends to throw floating objects shorewards.[1]

In the Punjab and the North-Western Provinces, the floating season commences early in November, as soon as the flood water of the rivers has run off, and continues until the middle

[1] The "*Indian Forester*," Vol. II, page 442.

of June as a rule; so as to allow of the drifted timber being rafted to the market before the rivers are again swollen by the monsoon. In the case of such rivers as take their rise in the high snowy ranges, the melting of the snow, which usually begins about March, materially increases the volume of water which comes down them; so much so, that the timber-catching arrangements placed in position at the beginning of the cold weather, have often to be dismantled long before the rainy season begins.

The timber-catching boom on the Jumna at Dakhpathar is maintained until the river is so swollen that it is in danger of being carried away, and is dismantled usually about the middle of March, though sometimes it can be maintained in position up to the end of May.

The time required for floating timber down a stream depends more upon the nature of the bed of the stream, the obstructions in it, and the volume of water it contains, than upon the quantity of timber launched. The larger the dimensions of the floated timber, the wider and freer from obstructions must be the floating river and the greater must be the volume of water in the stream. Sleepers on the Jumna take two months to travel over the 65 miles of river from Thadiar to Dakhpathar, while on the Pâbar, a tributary of the same river, the time required for floating 14 miles was one month. In March, when the Tons is swollen by snow water, scantlings and sleepers take only three weeks to traverse the same distance.

§ 124. METHODS OF CATCHING FLOATING TIMBER USED IN INDIA.—When the rivers become sufficiently large and free of obstructions to allow of the logs or scantlings being made up into rafts and floated down them, some arrangements must be made for the collection of the drifting timber and for the construction of rafts.

In India the logs or scantlings are usually intercepted by throwing a temporary obstruction across the river, of such a nature as to arrest the further progress of the floating timber. The obstruction can be removed when such a step is rendered necessary by the state of the river; or at the end of the floating

season, when there is no further need of maintaining it in position. The rivers which are used for drifting purposes in India and Burma are, as a rule, much too large, too subject to sudden floods, and contain a great deal too much water at certain seasons of the year, to allow of permanent obstructions, such as used to be erected in the floating streams in Europe, being constructed and maintained in position.

In Burma, *booms*, *i.e.* floating obstructions, are placed across the floating streams just above their junction with rafting streams, in order to intercept the floating teak logs. The logs are made into rafts above the booms and are passed out into the larger river.

The floating obstructions are moored to stout posts securely embedded in the banks, to standing trees, or to rocks suitably situated; while the boom itself floats in the stream in a loop between its anchorages on either bank of the stream.

The materials of which the booms are made vary in different parts of the country. On the Salween river, in Tenasserim, they are made of long stout canes twisted together to make a cable, while in the Katha Division in Upper Burma, they are constructed of teak logs connected by stout iron cables. In either case the boom lies directly across the stream.

The boom on the Jumna, North-Western Provinces, which is maintained during the cold weather from December to March, consists of a framework of deodar scantlings fastened together, and securely anchored to one side (the right bank) of the river. The boom lies diagonally across the stream and is kept in position by a series of guy ropes which pass round it and are fastened to windlasses on the left bank of the river. The inclination of the boom to the direction of the current can be altered by lengthening or shortening the guy ropes.

The scantlings and sleepers strike against the boom and are deflected from the main stream into shallow water, where they are taken out and stacked, or else made up into rafts and taken down the river.

§ 125. BOOMS ON THE TRIBUTARIES OF THE SHWELI RIVER.[1]—Booms made of teak logs are thrown across the

[1] Mr. E. A. O'Bryen Deputy Conservator of Forests, retired.

mouths of the tributaries of the Shweli river, Katha Division, Upper Burma, in order to catch the floating timber. The following points should be taken into consideration when choosing the site for the boom :—

(1) The stream should be as narrow as possible, so as to render the length of the boom (Burmese *thittaga*) as small as possible, and to minimise the danger of its being broken by the pressure of the logs against it.

(2) The banks of the stream should be high so that the water may not rise above them, and carry the floating timber round the ends of the boom all over the surrounding country. The best situation is one where the banks of the river itself are not very high but where there is higher ground, 50 or 60 yards away from the stream. The space between the edge of the river and the higher ground can then be utilised as a depôt for the logs which are caught by the boom.

(3) If possible, the boom should be erected a short distance below a sharp bend in the stream, so that the drifting logs may strike against the banks and lose their velocity before they reach the boom itself.

Having selected the site for the boom, two or three stout posts are firmly embedded opposite to each other, on either side of the stream. Posts have been found to be better than trees, as the latter are liable to be uprooted. These anchoring posts (*see* fig. 106) should be sunk at least ten feet into the ground, and made to slant slightly away from the bank of the stream. The posts are two feet in diameter and project about four feet above the ground surface. The pits in which these posts are placed are 12 feet deep and 9 feet in diameter; they are filled with stones and earth tightly packed. A log is laid horizontally about three feet below the surface of the ground in front of the slanting post, to further strengthen the anchorage.

The chains which fasten the logs, of which the boom is composed, are passed round, and fastened to, these posts. Ship

FIG. 106.

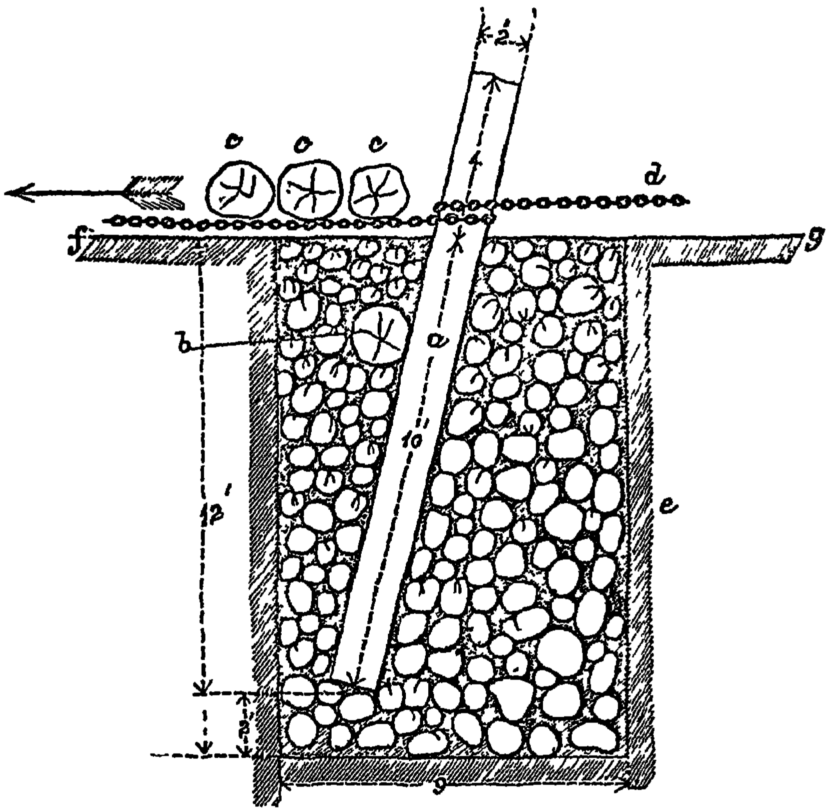


Figure 106 shows the method of anchoring the boom used to stop teak logs on the tributaries of the Shweli river: a *is one of the posts around which the chain is wound;* b *is the log placed horizontally to distribute the stress on the point when the river is rising. The pit* e, *in which the post is placed, is filled in with stones and earth;* c, c, c, *are logs placed on the chain to resist the lifting force imparted to the chains when the boom rises on a flood;* d *is the chain by which the boom is anchored. The end* d *goes to a second post similar to that shown in the figure;* f, g *represents the level of the ground. (Drawn by Mr. R. F. Lowis, late Extra-Assistant Conservator of Forests.)*

cables, 1½ inches in diameter, or steel wire ropes of the same size, are used in the construction of the boom.

When the water rises, there is a tendency to lift the posts out of the ground, and to prevent this, some logs (*c, c, c*, figure

106) are laid diagonally across the chain in front of the posts.

The boom is constructed of from three to five sections of logs fastened together by countersunk cables as shown in figures 107 and 108, each section consisting of three logs fastened to each other by chains (*see* fig. 108).

FIGS. 107 AND 108.

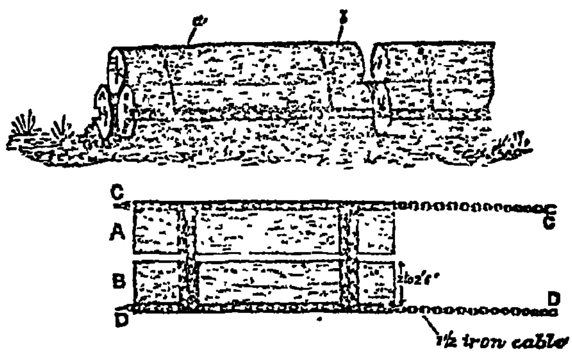


Figure 107 shows the construction of the Shweli timber boom : A *and B are known as tagathit and* C *as benthit ;* C *is fastened to* A *and* B *by chains* a b *as shown in the figure 108. (Drawn by Mr. R. F. Lowis, late Extra-Assistant Conservator of Forests.)*

Figure 108 is a section through figure 107 to show how the lower logs are fastened to the logs on either side of them. (Drawn by Mr. R. F. Lowis late Extra-Assistant Conservator of Forests.)

The boom does not lie straight across the river, but is bent down stream, so that the centre of the boom is from 8 to 10 feet further down stream than a line drawn straight from one anchorage to the other.

Each section consists of three logs, A, B and C (*see* fig. 107.) The logs A and B have the cable countersunk in them, whilst C lies on the top of A and B and is attached to them near either end by means of a chain passing right through it, and through the centres of the logs A and B. In still water the logs float as shown in figure 109. When the strength of the current is considerable, or a strain (such as that caused by the pressure

of the intercepted logs against the boom) placed on the boom, it assumes the position shown in figure 110.

FIGS. 109 AND 110.

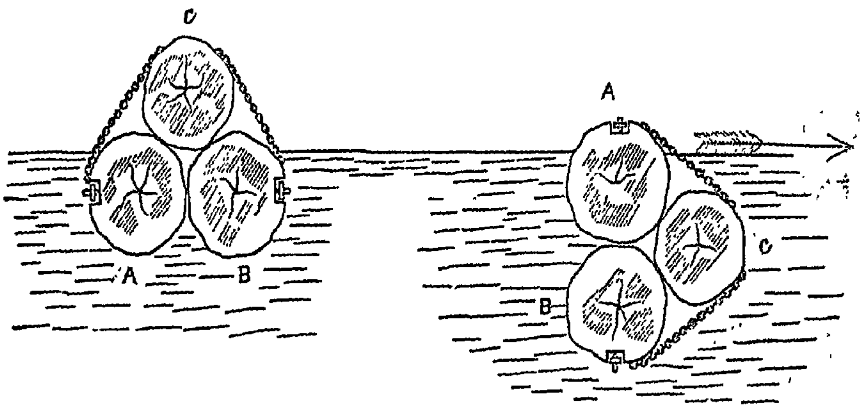


Figure 109 shows the position of the boom floating in still water, while figure 110 shows how it is further submerged when the current of the stream is considerable. (Drawn by Mr. R. F. Lowis, late Extra-Assistant Conservator of Forests.)

The logs used are from 2 to 2½ feet in diameter, so that when the boom is in the position shown in figure 110, its depth below the water is about 4 feet.

FIG. 111.

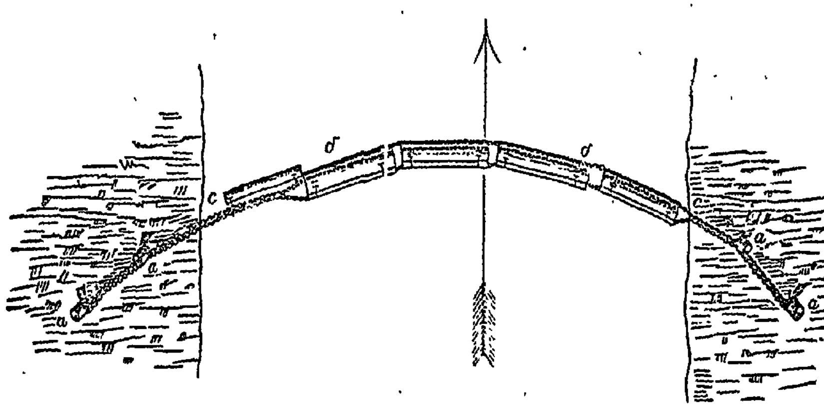


Figure 111 shows the Shweli timber boom in position. The arrow represents the direction of the stream; a a are posts to which the boom is moored; b, b are the logs which constitute the boom; c c the chain which binds the logs together. (Drawn by Mr. R. F. Lowis, late Extra-Assistant Conservator of Forests.)

When placing the boom in position, the chains are made fast to the posts on one bank of the stream, passed through the logs, and then hitched round the posts on the other bank. In order to get both chains to bear equally an elephant is attached to each chain where it passes round the post, and they are made to drag in opposite directions, and when the chains are taut they are firmly fixed in position by horse-shoe shackles.

When the timber comes down on a rise, a certain proportion of it is forced under the boom, but not much. As the logs underneath get jammed, a solid wall of timber, practically filling up the bed of the stream, is formed. To prevent the logs from forcing their way under the boom, any old letpan tree (*Bombax sp.*), or other rubbish, is allowed to accumulate in front of the boom.

When the flood has subsided, but the water is still high, one of the sections of the boom, that nearest the bank, which consists of one log only, is removed, and the timber is dragged out by elephants and kept on the bank until it is convenient to raft it. When the water is low, the chains can also be opened by means of a shackle placed in the chains between the end logs and the bank. The booms are never completely cleared of timber until the very end of the season, because, when the jam of logs against the boom is complete, it is not advisable to break it up. The large quantity of rubbish and fallen trees which are brought down by the freshets is not removed, as it forms a more or less elastic pad, in striking against which the logs lose their impetus. When the pressure on the boom is very great, it is not at all an uncommon thing to see logs squeezed out and forced bodily over the boom.

One drawback[1] to this kind of boom is the risk of the bed of the stream silting up behind the obstruction. This has actually happened in the Pyinmana Division, where the Bombay-Burma Trading Corporation have abandoned the use of such booms, as not only did the bed of the stream silt up, but hundreds of logs were buried in this deposit.

[1] Mr. J. W. Oliver, then Conservator of Forests, Eastern Circle, Upper Burma.

§ 126. In Lower Burma,[1] teak and other logs are generally made into rafts at or slightly below the junction of the floating and rafting streams. If the number of logs which come down a floating stream is small, they are allowed to float out into the rafting streams and are there salved by men in canoes, and fastened to the bank until made up into rafts. When the number of logs which come down a drifting stream is large, this method is most unsatisfactory, as not half the logs are salved at the mouth of the stream, the remainder become drift, and extra salvage dues have to be paid for them. In such cases, a boom is placed across the floating stream near its mouth. If the number of logs is not very large, the boom consists of a single or double row of logs stretching from bank to bank and lashed together at the drag-holes with cane. The logs are passed over the boom and made into rafts below it. In some streams, where logs come down by hundreds at a time, a more substantial boom must be constructed, as, for example, at the mouth of the Tonbinchaung. This boom is constructed on the same principle as those on the tributaries of the Shweli, described in detail above (*see* para. 125, page 196, *et seq.*).

In practice it is found that a large number of logs get buried in the sand behind the booms constructed in this way, and a considerable expense is incurred in digging them up.

If the logs fastened together by the chains will not float, more logs are lashed on to the boom by canes until it is sufficiently buoyant. A boom of this description is capable of catching any amount of timber; a few logs may go over or under it, but are caught by a similar boom placed a little further downstream. This second boom will stop the logs if the first one gives way.

The logs are passed singly over the booms and are made into rafts below them.

§ 127. CANE BOOMS ON THE SALWEEN.[2]—Figure 112, page 203, shows the construction of the cane booms used on the Salween river for catching teak logs. The booms which are two in number are erected about 60 to 70 miles above Moulmein, and from 10 to 20 miles below the lowest rapid. The

[1] The late Mr. G. Q. Corbett, Burma List.

[2] Mr. Max. H. Ferrars, Deputy Conservator of Forests, retired.

Salween is interrupted by more or less severe rapids which prevent rafts from being floated, or the river itself navigated by canoes even, for a distance of about 40 miles, so that the cane booms (Burmese *kyoaans*) of the Salween are a special feature.

The booms are composed of from six to ten heavy canes about 1 to 1½ inches in diameter plaited together. The booms float on the water, and are moored where the river is deep and sluggish and flows at the rate of about one mile an hour.

FIG. 112.

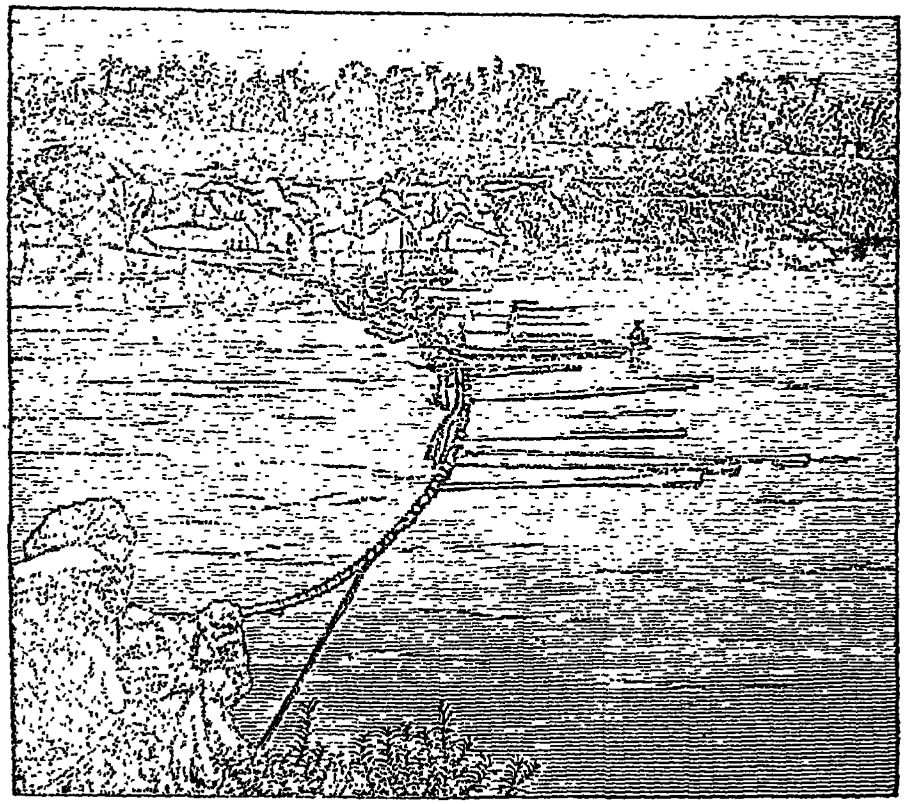


Figure 112 shows the construction of the cane boom used on the Salween to stop drifting teak logs. (From a photograph by Mr. Max. H. Ferrars, Deputy Conservator of Forests, retired).

The boom is rendered more buoyant by passing the cane cable over the ends of floating logs which are tied to it by canes passed through the drag-holes. The booms are placed in position in February, and are maintained till June, when the river rises and flows at the rate of from 4 to 5 miles an hour. The cane cables then snap and the logs are salved one by one by men in canoes.

The lengths of the cane booms on the Salween are 468 and 376 feet, respectively, indicating a width of river of about 400 and 300 feet, respectively.

There are always men on the watch, at the boom, who secure the logs as soon as they reach the boom, and take them inside another boom of floating logs tied together by cane, and moored to one of the banks of the stream. They are kept there until they are made up into rafts.

Smaller cane booms, consisting of one or two canes twisted together, are used on the tributaries of the Salween to catch the logs which are launched promiscuously in them and are *aunged* or allowed to float down them.

§ 128. DAKHPATHAR BOOM ON THE JUMNA.—The boom at Dakhpathar is constructed to intercept the sleepers and scantlings which are drifted down the Tons and Jumna. The rafting season is from the middle of November to the middle of March, and varies considerably from year to year with the state of river.

During the rains the Jumna is perpetually in flood, and floating is then impossible. The boom is put in position as soon as the extra volume of water brought down in the rains has passed off, and is maintained until the river becomes so swollen with snow water that the boom cannot stand the pressure exerted upon it by the stream. The boom has been put up as early as the 1st of November, and when the rains are delayed, maintained up to the 1st June.

The Dakhpathar boom consist of two parts:—

(1) Strong framework of sawn timber (the boom proper) anchored to the right bank of the river, and maintained in a slanting position by means of guy ropes which pass round the framework, and are fastened to windlasses on the left bank of the stream.

(2) A line of logs (vernacular, *line-dori*) fastened to the free end of the framework and reaching from it to the left bank of the river. This is also kept in position by guy ropes fastened to trees on the left bank.

FIG. 113.

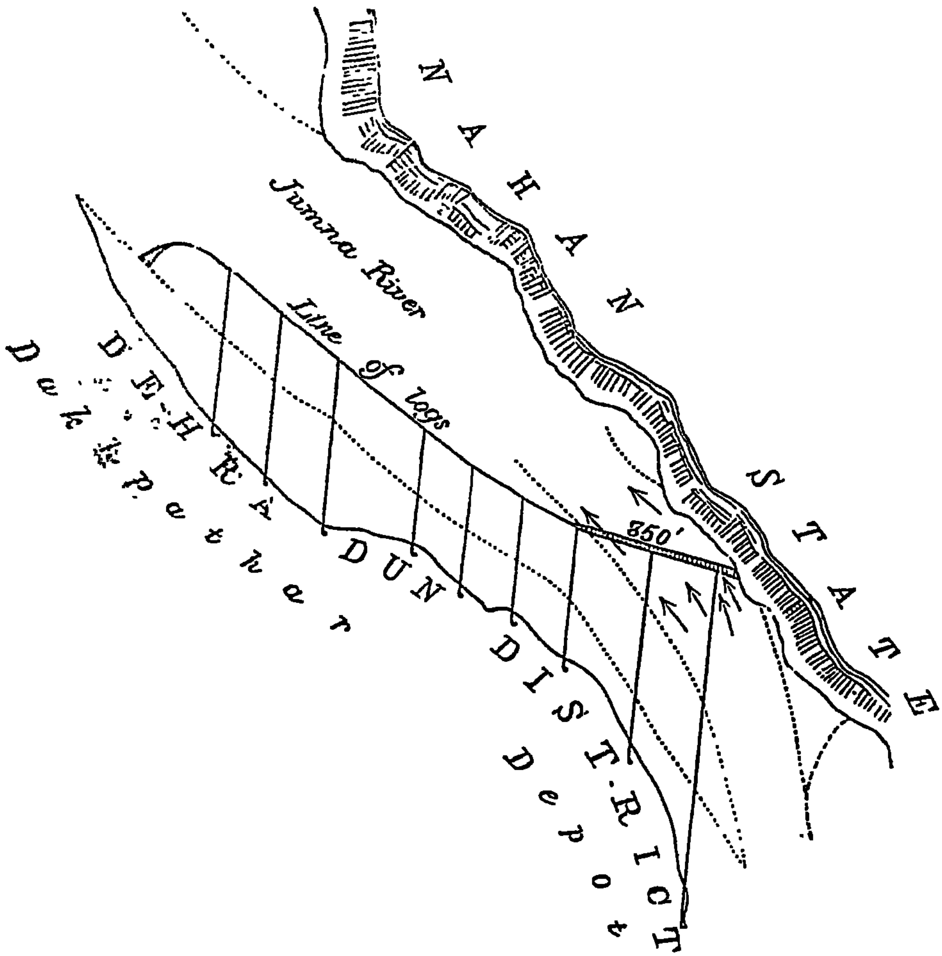


Figure 113 is a plan of the Dakhpathar boom on the Jumna river. The lines from the Dehra Dun shore of the Jumna river to the boom represent the steel wire guy ropes, which are fastened to windlasses. (Scale 16 inches = 1 mile).

The framework lies diagonally across the main stream, while the line of logs stretches across the shallow part of the river bed and guides the scantlings which are deflected from the main current by the framework into the shallow water near the shore, where they are made up into rafts or stacked in temporary depôts near the water's edge.

The framework of the boom is 256 feet long, when the river is at its cold weather level, and is inclined at an angle of 32° with the direction of the current at the anchorage on the right bank. The length of the line of logs which is fastened to the boom proper varies with the width of the stream and is often as much as 700 feet.

Construction of the framework.—The boom proper is made up of sections, each 10 feet long, fastened together. There are forty-one sections in all, but they are not all necessarily placed in position at the same time. The number of sections used at one time depends upon the force of the current and the consequent inclination which must be given to the boom. The normal number of sections in the boom in the cold weather is thirty-two.

One end of the framework is moored by strong wire ropes ($2\frac{5}{8}$ inches in circumference) to two substantial iron staples (6 inches in circumference) sunk 18 inches into the rock (a hard micaceous sandstone) which forms the right or Nahan bank of the river. The staples are leaded into the rock.

The boom is kept in any required position by means of five steel wire guy ropes ($1\frac{5}{8}$ inches in circumference) which are passed round the framework of the boom and fastened to windlasses on the Dehra Dun bank of the river. These wire guy ropes pass over small wooden guides fastened to the top of the framework of the boom and are thus prevented from slipping.

The windlass frame and drum or roller are made of sâl (*Shorea robusta*). A cast-iron toothed wheel is fitted on to either end of the roller, round which the wire rope is coiled, and a hook-shaped iron catch, pivoted to the frame of the windlass, works in the teeth of the wheel and keeps the roller in any required position.

Stout wooden levers fitting into holes cut in the roller allow of its being turned round, so as to tighten or loosen the ropes as may be necessary.

By lengthening or shortening the guy ropes the boom can be kept at any required inclination to the current of the stream.

Each section of the framework is composed of two deodar scantlings about 10 feet long, 15 inches deep and 6 inches wide (*see* fig. 114, page 208) which form the sides of the boom. The ends of these scantlings are shaped to form a scarf-joint as shown in the sketch, so that when fitted together a continuous surface may be presented to the sleepers impinging on them.

The side pieces are strutted apart by metre-gauge deodar sleepers (5 feet 4 inches long, 8 inches wide and 4 inches deep). These sleepers are dovetailed into the side pieces of the sections, six sleepers being fitted into each section. A sleeper is placed at a distance of 5 inches from either end of the spliced portion and the others are fixed equidistantly along the section. Vertically below the sleepers placed near the ends of the section, a second strut is added, the bottom of which is 3 inches above the lower edge of the side pieces of the framework.

In this way a light but strong boom is formed, which floats when the river is low, with about 13 inches of its depth submerged and 2 inches above the surface of the water. Any sleepers which pass under the first scantling are caught between the two sides of the framework, and rarely pass under the whole structure.

Holes are bored in the spliced ends of the sections, and when one section is fitted on to the other, thin wire ropes are passed through these holes and round the scantlings, so as to prevent the several sections opening out.

Four strong iron eyebolts are let into the sides of each section—two on either side—and, after the framework has been placed in position, two strong steel wire ropes, $2\frac{5}{8}$ inches in circumference, are fastened to the anchorage and passed through all these eyebolts, and fastened to the last one, so that, if the fastening between any two individual sections gives way, the framework will still be kept in position.

FIG. 114.

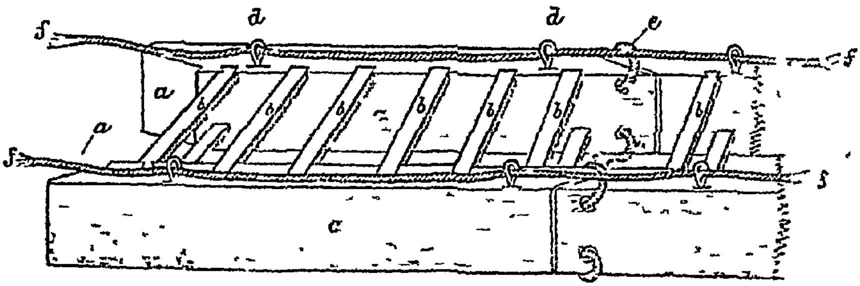


FIG. 115.

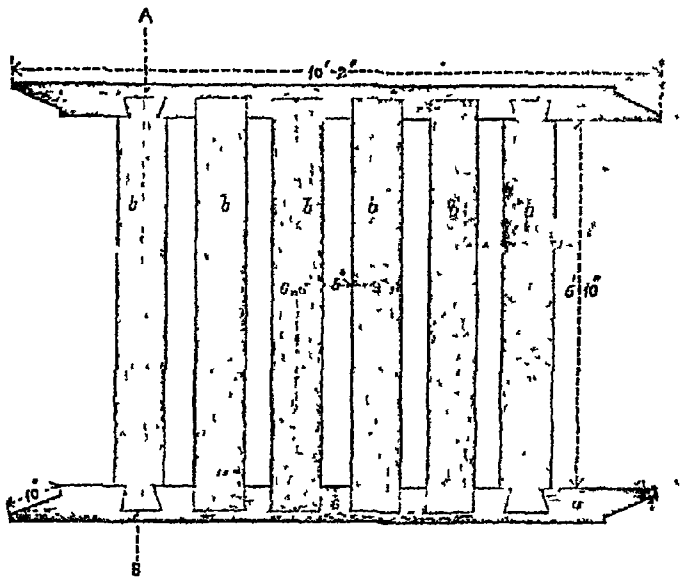


FIG. 116.

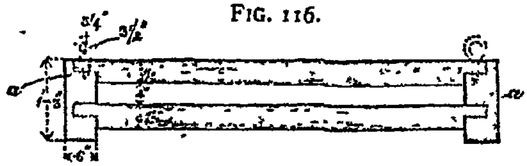


Figure 114 is a sketch of one of the sections of which the Dakhpathar boom is made up. a, a *are the bevelled ends of the section;* b, b *the metre-gauge sleepers by which the sides of the framework* c, c *are kept strutted apart;* d, d *are the eyebolts through which the stout wire ropes* f, f *running longitudinally are placed;* e, e *are small thin ropes by which the sides of the framework are joined together.*

Figures 115, (a plan), and 116, (a cross section on A B*), show the construction of one of the sections of the Dakhpathar boom.*

a, a *are the beams which form the sides of the framework;* b, b *the metre-gauge sleepers which serve as struts and keep the side pieces in position. These struts are two deep at either end of the section, those in the centre of the section being only one deep. Scale 2½ ft. = 1 inch. (Drawn by Mr. P. E. Plunkett, Extra-Assistant Conservator of Forests.)*

The line of logs is fastened to the last section of the framework. The logs used are of various lengths and sizes. They are fastened together by wire or grass ropes, which pass through holes, bored in the logs, about 4 inches from either end. This line of logs has grass guy ropes attached to it to maintain it in position. The guy ropes are attached to windlasses or to the roots of trees. The actual length of this line of logs depends upon the width of the stream, and, like the boom proper, can be increased at will. The timber framework lies across the main portion of the stream where the current is strong, while the logs are placed in the slack water and form a bay where the floating scantlings deflected by the framework from the main stream are collected.

§ 129. METHOD OF PLACING THE BOOM IN POSITION.—Five or six sections are taken some little way up above the site of the boom, on the Dun side, and are there joined together. A guy rope is passed round them. They are then pushed into the stream and guided across it by *mallahs* to the anchorage on the [illegible] side, where they are firmly fastened to the anchorage.

The rope attached to this portion of the framework keeps it from going too far down the stream until it is secured in position. Another length of five or six sections is similarly treated, and the same operation is continued until the required number of sections are placed in position. The line of logs is then formed along the bank of the stream, floated down it, and fastened to the end of the framework.

Mallahs are men who navigate streams, resting on inflated bullock or goat skins *(sarnais)*. They are employed annually to place the boom in position and generally look after it during the floating season.

These men are very expert in the use of their *sarnais*. They lie on the top of the inflated skin, with their legs and part of their bodies in the water, and move themselves along by using their legs and a small wooden paddle.

§ 130. MAINTENANCE AND WORKING OF THE BOOM.—The stronger the current of the stream, the greater is the strain on

the guy ropes and the more does the boom become depressed until when the current is very strong it becomes entirely submerged. When the current becomes too strong to allow of the boom being kept in position, the guy lines are loosened, and the whole structure is carried by the stream against the Nahan side. It is taken to pieces there, and the sections are brought across the river and stored on high ground, out of reach of flood. The guy ropes are stored in a godown until they are wanted the following year.

A line of planking, 2 feet wide, supported on cross pieces, 5 inches wide and 4 inches deep, is fastened along the centre of the framework to allow men to walk up and down the boom and prevent sleepers from striking end-on against it. These men are provided with boat-hook like prongs, with which they receive the sleeper and turn it, so that it slides along the framework to the shallow water. Any sleepers which have found their way under the framework are released and allowed to proceed to the shore. When the sleepers come down in large numbers, men are stationed on the boom day and night, in order to prevent it from being damaged by sleepers impinging against it and to prevent an accumulation of sleepers above it.

The floating of timber in the Tons is regulated by Government, and the launching is so arranged that a great number of sleepers do not arrive at the boom at the same time, and that the number that arrive daily is as nearly constant as possible. When a large number of sleepers arrive at the boom at the same time, the strain on it is very much increased and occasionally it has been found necessary to loosen the guy-ropes and let all the sleepers go down the stream in order to prevent the boom itself from being broken.

In the cold weather the river rises daily from 10 A.M. to 2 P.M., and then gradually falls till evening. As the river rises, the number of sleepers which come down increases and reaches its maximum about 2 o'clock each afternoon. When heavy rain falls, the number of sleepers which come down is very much increased. The following table shows the number of

sleepers and scantlings which are stopped annually by the boom :—

Season.	Number of scantlings.
November 1889 to June 1890 . .	295,971
" 1890 " 1891 . .	429,598
" 1891 " 1892 . .	497,916
" 1892 " 1893 . .	402,467
" 1893 " 1894 . .	146,356
" 1894 " 1895 . .	518,121
" 1895 " 1896 . .	651,407
" 1896 " 1897 . .	660,652
" 1897 " 1898 . .	721,233
" 1898 " 1899 . .	654,797

§ 131. COST OF THE BOOM.—The boom now in use was constructed in 1889 at a cost of R1,362. The cost of the establishment entertained and the repairs has been as follows :—

	R
1890-91	340
1891-92	727
1892-93	180
1893-94	...
1894-95	1,244
1895-96	1,065
1896-97	1,267
1897-98	1,140
1898-99	1,137

The cost of repairs (R727) in 1891-92 includes the purchase of new steel wire guy ropes.

The revenue from the boom has been as follows :—

	R
1890-91	...
1891-92	...
1892-93	1,378
1893-94	972
1894-95	3,252
1895-96	4,211
1896-97	4,826
1897-98	4,450
1898-99	3,296

The rates now levied on timber belonging to private individuals are—broad-gauge sleepers, 3 pies; metre-gauge sleepers, 2 pies; short small scantlings, 1 pie; rafters, 6 pies, 3 pies and 1 pie, according to the length and cross section.

§ 132. SUITABILITY FOR, AND PREPARATION OF RIVERS FOR RAFTING.—In order that a river may be suitable for rafting, it must contain sufficient water to allow of the raft floating without touching the bottom. Shallow rapids, over which rafts cannot pass without bumping against, or scraping along the bed of the river, are particularly obnoxious, but rapids do not necessarily render a river unfit for rafting unless they are studded over with projecting, or only just submerged rocks, against which the rafts might strike. The presence of a whirlpool may render rafting on a river difficult, if not impossible. The river should be sufficiently wide to allow of the raft turning round, if necessary.

The preparation of a river for rafting is similar to that described with regard to the preparation of a river for floating (*see* page 188, § 119, *et seq.*), except that there is no necessity to close the mouths of back-waters and side channels. Dangerous rocks and sunken logs should be removed by blasting, and rapids made passable or else avoided by the construction of side channels. The channel may be straightened, if necessary, where the current is too slow.

§ 133. SEASON FOR RAFTING.—In India rafts cannot be taken down large rivers when they are in flood, as not only do the rafts become unmanageable, but the streams are apt to spread out over their regular cold weather banks, and carry the rafts with them, leaving them high and dry as the flood recedes. This necessitates great expense in dragging the logs, or carrying the converted timber, back to the main stream and re-making the entire raft.

Consequently, the rafting season begins after the rains have ended and is continued as long as there is sufficient water in the river to allow of the rafts being taken down, or until the streams again come down in flood, owing to the melting of the snows at their sources or the commencement of the next rainy season.

The best time for rafting on the Irrawaddy is from November to March. From the latter part of March very high south-

winds prevail, and rafts are liable to get broken up in the heavy waves they encounter in long reaches.

Heavy woods, which are floated down with the help of bamboos, are never rafted until towards the end of the rains, when there is little or no chance of a high flood.

On the Salween no rafting is done until the logs have passed all the rapids, the lowest of which is 55 miles as the crow flies from Moulmein.[1]

Rafting, as practised in Burma, cannot be carried out on any river on which there are rapids. Drifting can be done in any stream in which there is sufficient water during rises. High water-falls, however, smash up logs and may prevent the stream from being used for floating. On some streams there are narrow, deep channels between rocks where elephants cannot go, and in such places logs may become hopelessly jammed.[2]

On the Jumna only sleepers, small scantlings and firewood are rafted, and the best season for rafting is from October or November to March or April. After April the river becomes swollen by the melting of the snow at its source, and rafting becomes more difficult, but can often be continued until the first burst of the monsoon in June.

§ 134. CONSTRUCTION OF RAFTS.—Rafts consist of logs or scantlings fastened together in such a manner that they will reach their destination intact. Logs are usually fastened together so that the length of the log is parallel to the direction of the stream; sleepers and short scantlings are, on the other hand, usually placed in rafts, with their length at right angles to the direction in which the stream flows.

The methods of fastening the logs or scantlings together vary from place to place with the nature of the materials available and the distance which the rafts have to travel. In India, rafts are generally tied together with cane, ropes made locally from grass, the fibrous bark of creepers and trees, or any other strong and sufficiently durable binding material.

In the Nilambur valley[3] (Madras Presidency) a raft usually consists of a large log of 80—100 cubic feet, supported by bundles of bamboos tied on to it to serve as floats. Two small

[1] Mr. J. W. Oliver, Conservator of Forests, Upper Burma.
[2] The late Mr. G. Q. Corbett, Deputy Conservator of Forests.
[3] Inspection note by the Conservator of Forests, Madras, Presidency (1895).

logs of 50—70 cubic feet are placed on either side of the bundles of bamboos and secured to them. These rafts are brought down the smaller tributaries of the river singly with the help of elephants and one or two men to Mambart. Here four small rafts described above are tied to each other, end to end, and taken down to Calicut, a distance of 50 miles, by one man in seven days. The man is paid R1 per raft of three logs and bamboo floats taken down to Calicut.

Burmese teak raft.[1]—In Burma, teak logs are fastened together with cane. The breadth of a raft depends upon the size of the rafting stream. In Upper Burma the raft is from 35 to 40 feet broad, composed of sixteen to twenty logs placed side by side. The number of logs in a raft depends upon the number of sections of which it is composed. From 112 to 130 long logs or 250 short ones are usually placed in a raft. Such a raft has a crew of five or six men, two of whom are in charge of the anchoring pole—a position which requires no slight knowledge and involves a certain amount of danger.

The rafts brought down the Sittang river have to pass through the Pegu canal in order to reach Rangoon, and in consequence only nine logs can be placed abreast, and a raft contains only 45 logs.

The usual number of sections in a Burmese teak raft is five. The logs placed in each section should be as nearly as possible the same length. The logs in each section are fastened together by passing a thick cane, about an inch in diameter[2] (Burmese *napathi*) passed through the drag-holes. On the top of the logs above the drag-holes, a small pole (Burmese *podán*) 9 to 15 inches in girth, is placed and firmly tied down with canes which pass through every drag-hole. Both ends of the section are fastened in this manner, whenever the evenness in length of the logs allows of this being done. Where the logs are not of the same length, the small pole (*podán*) is fastened as near the end of the logs as is possible, and is secured by canes passing round each log, and the *napathi* cane is not used. As the sections of the raft are made, they are fastened firmly together by tying a twisted cane rope to the drag-hole of a log of the first section made.

[1] Mr. E. A. O'Bryen, Deputy Conservator of Forests, Burma, retired.

[2] The local Burman prefers to use a small pole about 6 inches in girth instead of the *napathi* cane, as the latter is difficult to get. This, however, necessitates considerably larger drag-holes, which decreases the value of the logs.

Both ends of this cane are then secured and the loop thus made (Burmese *maung-gwin*) is passed under the *podán* of the second section, and strained taut by a small lever about 3 feet long (Burmese *maung-dôk*), which is then securely fastened to the first section. Four or five logs out of the sixteen or twenty logs which make up a section, are similarly treated.

A raft consists of five or six sections, if the logs are long, or from eight to twelve, if they are short. Along and outside each section are placed logs (*see* figure 117, page 216) which are longer than the sections to which they are attached, and these logs are securely fastened with canes to the outside logs of two contiguous sections. These logs (Burmese *leyans*) protect the ends of the *podáns* from being torn off or injured in case of a collision with the shore or another raft, and considerably stiffen the whole structure.

Starting at the front of the raft as it floats down stream, the different sections are—

(1) The leading section (Burmese *u-byit*).

(2) The section on which the anchoring gear is fixed (Burmese *that-ton-byit*).

(3) The section on which the house for the raftsmen is built (or *te-byit*).

(4) Then follow from two to eight sections which fulfil no particular purpose and which have no particular names; and lastly we have

(5) The steering section (or *pe-byit*).

The leading section (*see* figure 117, page 216) has a log placed across it at the very head of the raft. This log is called the *u-hngein-dôn* in Burmese, and has at either extremity, stepped 3 inches into it, two small sticks (Burmese *na-daing*) about 6 or 8 inches in girth and projecting from 15 to 18 inches above the logs into which they are stepped. These are used in stopping the raft when it is anchored for the night. Four twisted cane rowlocks, in which the steering oars are placed, are also attached to the *u-hngein-dôn*.

The second section (from the leading end) has also a log placed across it, at a distance of about 20 feet from the nearest

end of the leading section. On the middle of this log (Burmese *ón-dón*) rests the log that is used for stopping the raft (Burmese *that-dón*). This latter is fastened to the former by being placed between two uprights (Burmese *nat-thami-daing*) which project 2 feet above the *ón-dón* and are let into it to a depth of 3 inches. These uprights are tied together with cane to prevent the *that-dón* from slipping upwards; they are also firmly attached to the main body of the raft by cane ties. The end of this log projects 4 or 5 feet beyond the *ón-dón*. The *that-dón* is used as a drum, by means of which the mooring ropes can be gradually slacked off when the raft is being stopped.

FIG. 117.

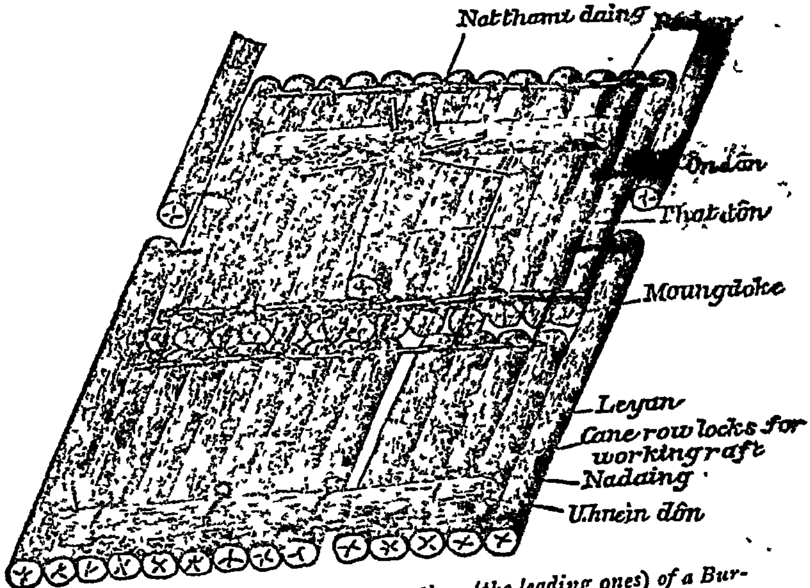


Figure 117 represents the first two sections (the leading ones) of a Burmese teak raft. There are usually from 5 to 7 sections in a raft. The Burmese names of the different parts of the raft are given. Section 3 only has a house for the boatmen, while the last two sections are similar in every way to the two first sections shown. The other sections have nothing particular about them which requires special notice. (Drawn by Mr. R. F. Lowis.)

On either side of this section, logs (Burmese *panthit*) are placed longitudinally, to each of which, six twisted cane row-locks are attached (Burmese *podáns*) which are used in manœuvring the raft. The lashings between the several sections are made so that they can be readily untied in case the raft grounds and has to be shoved off. The raftsmen's house is placed on the third section, which otherwise does not differ from those which succeed it.

The last or steering section has a log placed across it, similarly situated to the *U-hnein-dón* of the leading section. Four twisted cane rowlocks are attached to this log, and the steering oars placed in them.

It is proposed instead of the method of fastening the logs together described above to introduce an appliance used on the St. Lawrence river in floating down balks of timber. This consists of an iron wedge, about 4½ inches long, 1½ inches wide at the top, and 1¾ inches wide at the bottom, furnished with rings [illegible] inches in diameter. A *devil*, as it is called, is driven into the head of each log, and the logs are connected with one another by a 40-feet chain of three-fourths of an inch iron, fitted with a large ring at one end, and a cross-bar at the other which can be passed successively through the rings. The *devils* cost 5*d.* or 6*d.* in Liverpool, and allowing even for a loss of 40 per cent. every year, the extra cost would be more than covered by the saving in timber rendered possible by being able to do away with the second drag-hole.

§ 135. MANAGEMENT OF A TEAK RAFT.[1]– The raft is guided from the leading, second or last section as may be necessary. The raft is usually guided by four oars, two of which are at the leading end, and two at the back section. A raft often slews round, and the back section then becomes temporarily the leading one. Rafts are not moved voluntarily at night, but are made fast to the bank every evening. When it is desired to stop the raft[2]

[1] C. Junghen, Esq., of Macgregor & Co., Timber Contractors.

[2] E. A. O'Bryen, late Deputy Conservator of Forests.

two of the raftsmen put off in a small boat carrying with them a 3½-inch coir rope, to one end of which is attached the anchoring pole (*Gwe-daing*) which is about 12 feet long and about 1 foot in girth, and is sharpened at one end, so as to allow of its being easily driven into the ground.

The other end of the rope has been carried round the *Na-daing* (*see* figure 117, page 216) furthest away from the shore and hitched round the *That-dôn* (see same figure). The immediate effect of this is to turn the head (leading section) of the raft upstream as soon as the rope is taut. The rope is gradually slacked off to prevent its being broken by the sudden strain put on it. As soon as the raft has almost stopped, another rope, generally made of plaited cane, about 5 inches in girth, is carried ashore and fastened to another anchoring pole, in a similar manner to that in which the first was. The other end of this rope is passed round the other *Na-daing* (which is now furthest away from the shore) and is also hitched round the *That-dôn*. The effect of this is to completely stop the progress of the raft and at the same time to bring it close alongside the bank. The latter part of the process has to be repeated as many as five or six times before the raft is finally anchored, if the current is strong.

When the raft is unmoored, the head is allowed to swing round so that the raft travels in one position.

In Upper Burma the raftsmen are engaged by contract and are, as a rule, paid a fixed sum for rafting so many logs (the materials being supplied to them) to a stated place.

Messrs. Darwood & Son pay R1-4 per log from the mouth of the Shweli river to Mandalay *viâ* Panhlaing, a distance of about 150 miles, and R260 to R300 per raft from there to Rangoon (about 660 miles). This latter journey takes from forty to sixty days according to the height of the water.

Rafting to Rangoon costs R3 per ton from places on the Irrawaddy; R2 per ton from places on the Hlaing and Pegu rivers; and R4 per ton from places on the Sittang river.[1]

[1] Mr. P. J. Carter, Conservator of Forests, retired.

§ 136. LOSS IN TRANSIT.—Messrs. Darwood & Co. employ two steam launches in the rains in carrying rations and material as near as possible to the forests where the teak logs are being work out; and in the dry season in conducting their rafts, hauling them off sand banks, etc. The consequence was that in 1892-93 only 0·05 per cent. of the logs that paid duty at Tigyaing above Mandalay failed to reach Rangoon.

§ 137. TIMBER RAFTS IN THE ANDAMANS.—At present in the Andamans no drag-holes are made in the logs extracted, and the only practical method tried up to date that is not too costly is to place two or three poles across the logs and to bind them together with split cane.

When rafts have to be towed by a launch in a sea way, or against wind and tide, it is advisable never to have more than three logs abreast and generally only two. The rafts should be made in sections, each section consisting of two or three logs fastened to each other as described above, and to allow greater play, the sections should not be too close to each other; a long rope is passed from end to end of the raft, passed round each section and securely fastened to the poles of each section.

§ 138. Rafts of *In* (*Dipterocarpus tuberculatus*) are brought down the Sittang river, consisting of 25 logs in five sections; 1,200 bamboos being used as floats for one raft; 6,000 bamboos are usually provided for rafting 100 *In* logs to allow for the construction of huts and breakages. The raft is taken down by two men. The bamboo floats are about 2 square feet in section, tied together as close as possible with cane. The floats carry the two cross poles *U-hnein-dón* which are stronger than those of teak rafts. *In* rafts cannot be moved before November when the river has fallen and the current is less strong than in the monsoon. They take a long time to float down the stream. On some streams, *In* logs are floated by being lashed alongside boats or boat hulls; two or four logs according to their size, being fastened to each boat.[1]

Pyinkado (*Xylia dolabrifomris*) logs are floated down the Ngawun river, either lashed to the sides of boats or else bamboos

[1] Mr. P. J. Carter, Conservator of Forests, retired.

are fastened to the sides of each log with canes and creepers. Ten of these logs with the bamboos are placed side by side to form a section of the raft, and five such sections make a raft.[1]

The following is an account of the construction of rafts of bamboos on the same river. The bamboos have small pieces cut out similar to drag-holes, 20 bamboos are placed side by side, and a piece of bamboo passed through the holes; then five such lots of 20 bamboos are placed on the top of one another and fastened round with strips of bamboos and form what the Burmans call a *kadon*, each *kadon* consists therefore of 100 bamboos. Five *kadons* are made and placed side by side and fastened to two poles, one of the poles being near the drag-holes and the other across the centre of the *kadons*. Five more *kadons* are then made and fastened to the centre pole on the top of the other *kadons*, but leaving about 6 feet of the lower *kadons* uncovered. Five more *kadons* are then made and similarly treated, until the raft is completed. A raft generally consists of 20 rows of *kadons* and therefore contains 100 *kadons* or 10,000 bamboos.

§ 139. RAFTS ON THE JUMNA.—On the Jumna, sleepers and scantlings are rafted to Delhi and other markets in the plains. The sleepers or scantlings are arranged in transverse rows and are placed two deep. They are lashed to each other and to sleepers placed lengthwise across them near either edge with ropes made of bhabar grass (*Ischæmum angustifolium*) which is found locally. The ends of the sleepers, which are placed longitudinally, overlap as shown in figure 118.

The sleepers placed longitudinally give the raft considerable rigidity. A sleeper or scantling, placed on its smaller side, is fastened across the longitudinal sleepers at either end of the raft and is used in steering it down the river.

The rafts are taken from Dakhpathar to Bogriwala, a distance of 28 miles, and then down the Western Jumna Canal, 164 miles more to Delhi. The time occupied in the journey is on an average $1\frac{1}{2}$ months.

[1] Mr. G. Junghen, of Messrs. Macgregor & Co.

FIG. 118,

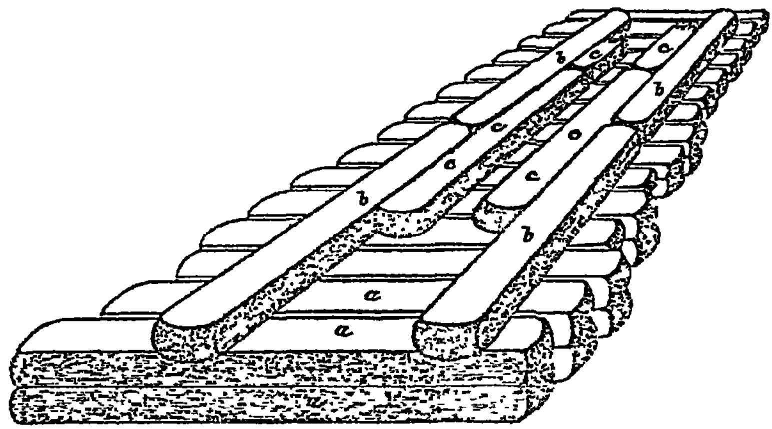


Figure 118 shows the construction of a Jumna sleeper raft. The sleepers, are placed sideways two deep, and near either end of the sleepers, two lines of sleepers are laid longitudinally, on the top of these, breaking joint with each other, each pair of sleepers is tied by grass ropes to the two longitudinal rows of sleepers as shown in the sketch. A sleeper tied on above the longitudinal rows of sleepers at the end of the raft is used in steering it, but is not shown. The ropes tying the sleepers together have been purposely omitted from the figure. (From a photograph by Mr. N. Hearle, late Deputy Conservator of Forests.)

The rafts are taken down by two men, who are provided with long, thin sâl (*Shorea robusta*) poles, 20 feet long, which they use to push the raft off the banks, and to guide it round corners and past difficulties. These poles are also used to steer the raft with, and, if necessary, as oars. One man is stationed at the front end, the other at the back end, of the raft, and move about the raft whenever it may be necessary to push it off any rocks or to guide it past shallow places. The rafts are moored to the bank by night.

The raft is guided to the bank in a smooth reach of the river, a rope tied on to one end is taken ashore and the raft,

which is moving very slowly, is soon brought to rest; the rope is then fastened round some large stone on the bank of the river.

The rafts contain 160 metre-gauge (about 6 feet long) or 120 broad-gauge sleepers (about 10 feet long). They are about 50 feet long and from 6 to 10 feet wide.

When sál scantlings are rafted down the Jumna, they are made up into rafts with chir (*Pinus longifolia*) scantlings, and can in this way be floated down the river. Sál by itself will not float. Bamboos and reeds (*bindh*) are also used as floats for sál.

§ 140. SEA-GOING RAFTS.[1]—Large rafts which can be towed long distances by sea have been constructed in America since 1888, under a patent taken out by Mr. Hugh R. Robertson of St. John N. B. These have been used for taking timber from the bay of Fundy to New York, and also from Stella on the Columbia River (California) to San Francisco.

The raft is constructed in a skeleton frame similar to that used for the construction of large vessels, and conforms in all respects to the lines of the whale-back type of ship. The only difference being that the frame is anchored to a row of piles by means of loose anchor boxes, with sufficient play to admit of the frame falling and rising with the tide. The frame is constructed with an ingenious arrangement of key joints which, on being withdrawn, admit of its falling apart in two complete halves thus releasing the raft when constructed.

The logs are hoisted by means of donkey engines into the cradle. When the raft is completed, the top of the cradle will be on a level with the water, while the top of the raft will be about 10 feet above it. When all the logs have been hoisted into the cradle, the raft will assume the shape of a huge cigar tapering at both ends. It will then be bound together with heavy chains.

The main chain runs through the centre of the raft from one end to the other, and is of $1\frac{3}{8}$ inch iron. Running at right angles to this main chain at intervals of 12 feet, and connected

[1] "Timber Traders Journal," 5th October 1895.

to it, are cross chains of 1¼ inch iron which run to each side of the raft. The chains which encircle the raft are of 1⅝ inch iron, are placed at equal intervals of 12 feet, and are fastened to the cross chains above referred to.

All the chains are connected with the main chain in such a manner that when the strain of towing comes on to the main chain, the strain will be brought to bear equally on every chain of the structure. In addition to this a bulkhead of heavy timbers is placed on each end of the raft and kept tightly in place by heavy steel cables running through the raft from one bulkhead to the other.

A raft, when completed, will contain 10,000 logs varying from 30 to 75 feet in length. The rafts are as much as 525 feet long, 52 feet wide, 30 feet deep, and will draw from 20 to 21 feet of water. The girth amidship is 139 feet and at the ends of the tapering sections 45 feet. The rafts are towed by powerful tugs and under favourable circumstance will travel 70 miles a day. They cannot stand storms, and should be taken by sea only at times of the year when calm weather is likely to be experienced.

Part VI.—WELLS.

SECTION I.—CHOICE OF SITE.

§ 141. A *well*, in the ordinary meaning of the term, is an excavation in the earth sufficiently deep to reach a source of underground water yielding a permanent supply for drinking or other purposes. The source tapped is usually either a deep-seated spring or a natural underground reservoir. The depth at which water is likely to be found depends upon the amount of available rainfall and the character of the underlying strata.

In many of our Indian forests, where there is so much bad water, wells are sunk in order to obtain water that has filtered through several feet of sand or earth, and in consequence is purer. When a well is dug with this end in view, its depth should not be less than 25 feet.

Hollow cylinders of brick-work or concrete, also termed "wells," are sunk in soft earth or sandy river beds in order to obtain stable foundations for bridges and other structures; these are considered to be beyond the scope of the present work.

AMOUNT OF AVAILABLE RAINFALL.—The original source of all supplies of fresh water is rain or snow. The rain or snow which falls, and is not evaporated or absorbed by vegetable growth, either runs off the surface of the ground or through the upper layers of the soil into streams, or else sinks deeper into the soil and finds its way through crevices in the rocks and through porous strata into natural reservoirs, or deep-seated springs. When underground water escapes out of the side of a valley it forms a surface spring.

The *available rainfall* of a district is that part of the total rainfall which, after deducting losses of all kinds, is stored up in natural reservoirs, or runs into streams. The proportion

between the total and available rainfall varies very much from place to place and depends upon the volume and intensity of rainfall, the compactness or porosity of the soil, the slope of the ground, the nature and luxuriance of vegetation on it, the temperature, the quantity of moisture in the air, and the presence of artificial or natural drainage channels. The amount of available rainfall is greatest where steep surfaces of granite, gneiss or slate abound, as in such localities nearly all the rainfall is available. It is least in chalk and limestone formations. On ordinary flat, cultivated country about half the rainfall is available. Deep-seated springs receive from 0·3 to 0·4 of the total rainfall of a district.

CHARACTER OF THE UNDER-LYING STRATA.—Where permeable strata overlie an impermeable stratum, water will generally be found at the line of junction. Limestone and chalk permit rain water to pass through them freely, and are therefore likely to contain no reservoirs of water which can be tapped by shallow wells; a deep well may tap an underground accumulation of water. A well sunk near the bank of a sluggish stream will probably reach a permanent supply of water at a depth only a little below its lower water level; provided that the strata through which the river flows are not altogether impermeable. If the water falling on the slopes on either side of the river drain into it, a source of supply will probably be tapped in the underground percolating water before reaching the level of the water in the river. The quantity of water which a water-bearing stratum can yield depends upon the area of its receiving surface, and upon the available rainfall.

CHOICE OF SITE.—A site for a well should be chosen after examining any existing wells in the neighbourhood and determining as far as possible whether the stratification around the existing wells and the proposed site for the new well is similar or dissimilar. The relative level of the ground surface at the proposed site and at the existing well should be noted, the lowest point may involve a smaller depth of excavation, but will introduce a risk of pollution from surface drainage unless this eventuality is specially guarded against when the well is

sunk. Where the well is required for a dwelling-house, camping-ground or nursery, the choice of site is necessarily limited.

If no wells exist in the neighbourhood, the height of the proposed site of the well above, and its distance from, the beds of the neighbouring streams, should be ascertained, as it is possible to intercept at a reasonable depth below the surface a portion of the underground percolating water which is flowing towards them. The character and dip of the underlying strata, as shown by their exposed outcrops in the neighbourhood, should be examined with reference to the probability of tapping some natural reservoir of water at a reasonable distance below the surface. If we find a set of impermeable beds cropping out below a series of permeable ones, it is probable that we shall find water near the surface.

Figure 119, below, and figs. 121 and 122, page 228, are sections of permeable beds resting on impermeable ones, where a good supply of water may be expected.

If the rain falling on the area sinks away slowly, it may be inferred either that there is an impermeable stratum at no great depth, or that the permanent underground water level is near the surface. If the above investigations do not give us any satisfactory information, and it is necessary to sink a well, we must either make trial borings or sink a shaft until we come to water.

FIG. 119.

A

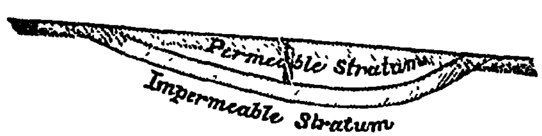


Figure 119 shows diagrammatically a good position for sinking a well. The shaded portion represents a stratum impermeable to water, while the portions which are not shaded represent strata permeable to water. A is the shaft of the well.

FIG. 120.

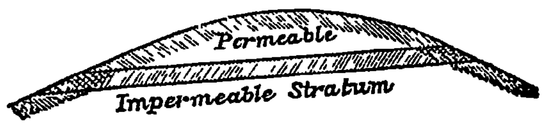


FIG 121.

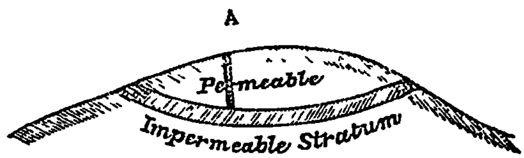


FIG. 122.

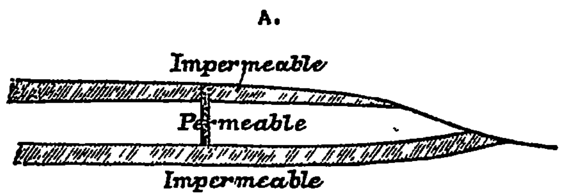


Figure 120 shows diagrammatically a bad position for sinking a well. The shaded portions represent impermeable, and those not shaded permeable strata.

Figures 121 and 122 show diagrammatically positions in which a certain quantity of water will probably be found. The shaded portions represent impermeable, and the non-shaded portions permeable strata.

§ 142. ARTESIAN WELLS.—When a series of impermeable beds rest on a set of permeable strata in the form of a synclinal curve, as shown in figure 123, and below these again another series of impermeable strata exist, then a hole bored through the upper impermeable beds will release the water imprisoned in the permeable stratum by the impermeable beds above and below, and the water will rise in the bore hole which has been made. The height to which the water will rise depends upon the level of the imprisoned under-ground water. When, as in figure 123, the outcrop of the permeable stratum is above the surface of the ground where the well is dug, the water may rise in the hole bored until it flows as a jet above the surface of the ground. The maximum water-supply will be obtained when the upper surface of the impermeable bed below the permeable one is reached.

FIG. 123.

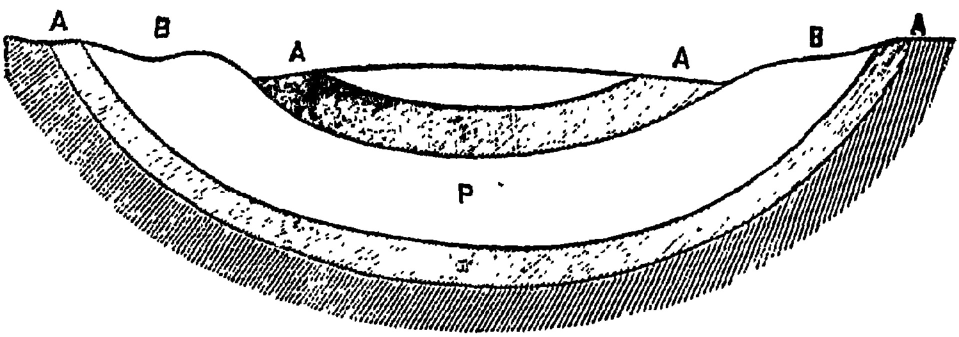


Figure 123 shows diagrammatically the disposition of strata which would allow of an artesian well being sunk. I, I, *are impermeable strata, while* P *is a permeable one.* A, A, A, A, *are the outcrops of the impermeable, and* B, B, *those of the permeable beds.*

The name Artesian is derived from that of a French province (Artois) where wells sunk in the strata described above have existed for a very long time.

Mr. H. B. Medlicott,[1] of the Geological Survey of India, in his paper on Artesian borings in India, states that the disposition of the strata above described rarely occurs in nature except where the artesian conditions have been produced by disturbances, causing partial upheaval and the visible bending of the strata.

He further states that "the essential conditions of the phenomenon are fulfilled, wherever a body of water confined in an inclined channel, of whatever dimensions, is arrested or retarded by a total or partial obstruction in its progress to its point of discharge, so as to be pressed back above that level, a state of permanence being attained when the increase of pressure so produced causes a discharge equal to the supply of water at the upper end, or when overflow takes place there." "These conditions," he adds, "are produced continually in Nature by the ordinary process of formation of sedimentary rocks, independently of any turning up of the strata either from the original form of the floor of depression or by subsequent disturbance," and "that strictly horizontal deposits are very exceptional, for there is always greater deposition on the side from which the sediment is derived, and that subsequent disturbances would generally increase this condition of slope." He further adds: "The confined water channel mentioned above is produced by the distribution of fine and coarse deposits by alternation or by the latter covering the former."

SECTION II.—CONSTRUCTION OF WELLS.

§ 143. Wells may be either temporary or permanent. If a well is required for a short time only, all that is necessary is to sink a shaft of dimensions that will allow of the men excavating it to work efficiently, and of sufficient depth to yield the quantity

[1] "Records of the Geological Survey of India," Vol. XIV, Part 3, 1881.

of water required for the daily consumption. If the soil is sufficiently stiff to prevent the sides from falling in, no lining is necessary; but if the earth is not stable, then the cheapest lining procurable, generally wood, or twigs woven together (wattling), should be used.

In Oudh, large hollow sál trees, called *dúnds*, are often used for lining small wells; they last for a long time and cost very little. The centre of the hollow trunk is chiselled out from the inside and sunk into the narrow well-pit.

If the well is to be a permanent one, it should be carefully lined to keep the sides from falling in and to prevent any surface drainage from entering into the well and contaminating the water. The lining may be made of cut stone, bricks set in good hydraulic mortar, earthenware rings, zinc-coated corrugated iron, or wood. The nature of the lining selected will depend upon the degree of permanency of the well, the supply of water required, and the materials and money available for its construction.

The diameter of a well depends upon the amount of water required, and on the rate at which the well can refill itself. Speaking generally, for ordinary forest purposes, such as camping grounds, the inside diameter of the well should not be less than 4 feet.

§ 144. METHOD OF CONSTRUCTING A TIMBER-LINED WELL.—Wells lined with wood are usually made square in plan. The timbering consists of square frames, called *settings*, which are made up of four beams (*sills*), laid horizontally and kept apart by vertical props. A *walling* of boards is placed on the outer side of the settings. The settings are usually placed 6 feet apart, and the vertical props are kept in position by spikes 6 inches long driven into the *sills* of the setting as shown in figure 124.

The size of the sills depends upon the dimensions of the well, and may be as much as 12 inches square.

If the soil is sufficiently stable to stand by itself, the shaft may be first sunk to its full depth and the timber lining built up

FIG. 124.

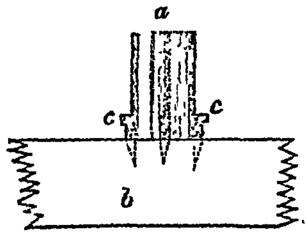


Figure 124 shows how the vertical props are fastened to the sills of the setting; a is the vertical prop; b the sill; c, c, c, the spikes by which the vertical prop is kept in position. Scale 2 feet = 1 inch. (After Rankine.)

from the bottom in the ordinary way, but if the soil is unstable, we must construct the lining from above downwards.

In this case the shaft is first sunk in the ordinary way as long as the sides will stand by themselves, and a setting is placed in position at the bottom of the shaft thus made, after it has been first carefully levelled, and the timber lining built up to the surface of the ground. A small pit is then dug in the centre of the shaft to a depth of 6 feet, and at the bottom of this pit a small wooden block with bevelled edges, called a *foot-block*, is placed in position.

Notches are then cut through the earth which forms the sides of this small pit, and wooden props introduced in them. The lower ends of these props rest against the foot-block, and the upper ends support the lowest sill of the wooden lining which has been placed in position. These props are called *raking props*. The pit is then enlarged to the size of the shaft above, another setting is placed on the bottom of the pit, which should first be carefully levelled; vertical props are introduced to support the setting above. The raking props are then removed and the planking placed in position, and the same operation continued until the required depth is reached.

FIG. 125.

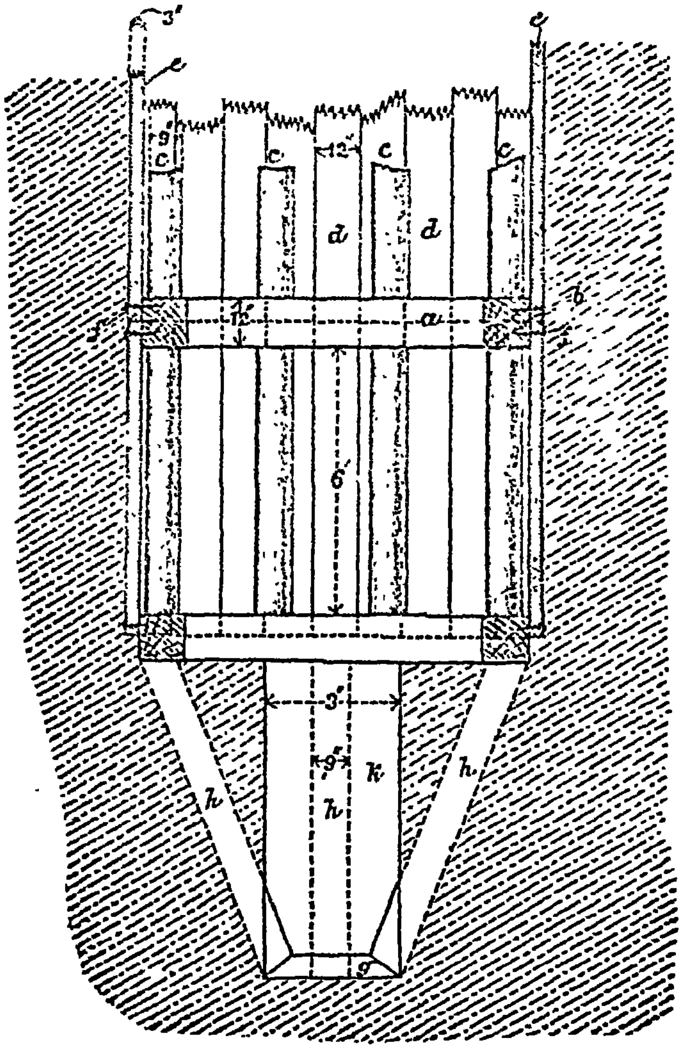


Figure 125 is a longitudinal section through a timbered shaft to show how the timbering is put together and how such a well is dug in unstable soil. a, b *are sills of which the settings are composed;* a *is in elevation;* b *is in section;* c, c, c, c *are the posts which keep the sills apart. They are fastened to the sills as shown in fig. 124;* d, d, e *are the boards which form the walling of the shaft;* d, d *are in elevation;* e *in longitudinal section;* h, h, h *are the raking props which support the lowest setting. The lower ends of these props rest on the foot-block* g; h *is the small pit which is dug, and at the bottom of which the foot-block is placed. Scale 4 feet = 1 inch. (After Rankine.)*

If water, carrying sand, comes through the joints between the planks of which the walling is composed, straw placed behind the boards will prevent its entry into the well shaft.

§ 145. STONE OR BRICK-LINING.—Wells lined with stone or brick are usually cylindrical in form. It is usual to carefully point the joints of the brick or stone-lining of a well with a cement mortar. A layer of lime plaster 2 inches thick placed over the inside of the well-lining is recommended as a much more efficient protection against the percolation of water through the well-lining.

When the soil through which the well is being sunk is not sufficiently stable to stand in a vertical position by itself, the lining is constructed on a wooden drum or *curb* as it is called.

Well curbs are also made of iron and steel.

A well curb consists of a flat ring made either of timber or iron, having a slightly larger external diameter than that of the well to be constructed. If the curb is of wood, it is often made 3 or 4 inches wider than the thickness of the well-lining itself.

The upper surface of the well curb is flat, and on it the brickwork of the well-lining is built. The lower surface of the well curb is bevelled (*see* fig. 127, page 235) so as to form a sharp cutting edge which facilitates the sinking of the shaft. The breadth of the curb may be 6 or 10 inches, according to the thickness of the well-lining, and the depth from 6 to 10 inches. The best woods for the construction of well curbs are gûlar (*Ficus glomerata*), banyan (*Ficus bengalensis*), pipal (*Ficus religiosa*), mango (*Mangifera indica*), semal (*Bombax malabaricum*), jâman (*Eugenia Jambolana*) and sâl (*Shorea robusta*).

The construction of a masonry-lined well is begun by digging a large pit with sloping sides 20 feet deep and then a vertical shaft as deep as the nature of the soil will permit. This procedure allows of the curb being put down at a much lower level than if the sides of the shaft were dug vertically down from the surface of the soil.

The bottom of the shaft is then very carefully levelled and the curb laid on it in a perfectly horizontal position. The hollow

FIG. 126.

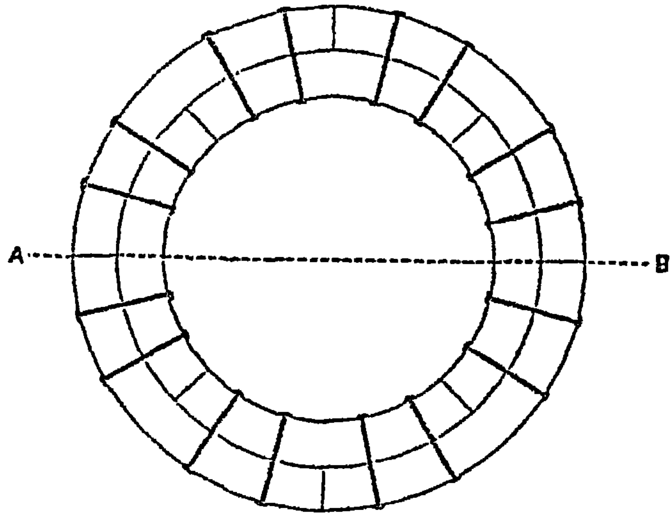


FIG. 127.

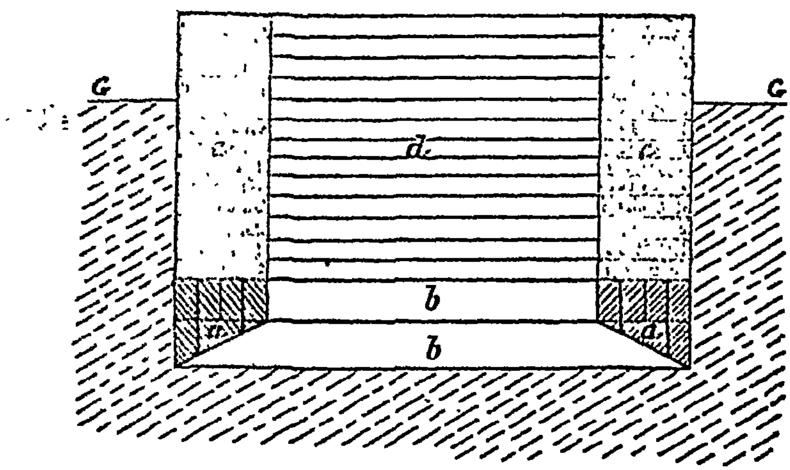


Figure 126 is plan of a well curb, formed of three pieces of wood bolted together. Only two of these pieces are visible in the plan.

Figure 127 is a sectional elevation of the curb along the line A B, with some of the brick-lining in position. a *is a well curb in section;* b *is part of the same in elevation. In section the curb is made up of 3 rings, 2 of rectangular section above and one of triangular section below;* c *is the well-lining in section;* d *the same in elevation;* g, g *is the level of the ground.*

cylinder of brick or stone which forms the lining of the well is then built upon the curb, care being taken that accretions of equal weight are built up diametrically opposite and that one course is completed before another is commenced, so that the curb may be always equally loaded all round, and will consequently sink in a truly vertical position. When the brickwork has reached a height of about 4 feet above the ground, the earth or sand should be dug away from the interior of the curb, evenly all around, so that the lining may descend in a truly vertical direction without cracking.

To force the hollow cylinder into the ground it may be necessary to impose a load, which must be placed symmetrically so that the centre of gravity of the load is exactly in the vertical line of the axis of the hollow cylinder.

It is very important that the well-lining should descend truly vertically. To test the truly vertical descent of the lining, four long weighted strings (plumb lines), placed at equal distances from each other, are allowed to hang down, inside the well, close to the lining itself. So long as these plumb lines all hang down freely and the weights are equidistant from the well-lining, the latter is descending vertically, but if the well-lining is not descending vertically, one of the weights will be found to be closer to the well-lining than the others, and this will indicate the side which has sunk more than it should have. In order to bring the well-lining once more vertical, the top must be unequally loaded, the greater load being placed on the side which is highest until the well-lining is once more brought into a vertical position.

The greatest care must be paid to the proper bonding of the brickwork. Only the best procurable materials should be used. Specially moulded radial bricks or ordinary bricks may be used. If the diameter of the well is small and ordinary bricks are used, they must be cut or rubbed down to the truncated wedge shape required by the curve of the well-lining which is being made before being used, so as to avoid mortar joints of uneven thickness.

When the curb has been undercut for some depth, and the lining will not sink even when weighted, the explosion of half an

ounce of dynamite at the bottom of the shaft causes the lining to sink; this is due to the vibration set up, which reduces the friction between the well-lining and the surrounding earth. (*Mr. F. A Lodge.*)

If the brick or stone-lining will not sink of its own weight or by using the above-noted methods, owing to the friction of the earth against the lining itself, a new curb must be constructed, having an outside diameter slightly less than the internal diameter of the shaft, and on this brick rings of correspondingly smaller diameter are built as before.

If the ground is very stony, this system of sinking a well cannot be adopted, and in such ground a curb is made and laid at the bottom of the pit first excavated and the brick-work cylinder built on it. The well is then sunk in a manner similar to that described in the case of a well with a wooden lining, and a new curb laid down each time the shaft is lengthened.

It occasionally happens that the sinking of a well is stopped on account of the interposition of a bed of *kankar*, or hard soil, below which a sufficient supply of water would be found. In this case it may be necessary to pierce the bed with a shaft of 2 feet less diameter than that of the well.

A large supply of water may frequently be obtained by carrying the curb to a moderate depth below spring level and boring a 6-inch augur-hole to a depth of 20—25 feet. If an iron cylinder be passed down and left in the shaft, with its top projecting 3 or 4 feet above the bottom of the well to prevent its being choked, success will be assured.

Single brick wells.—In addition to the ordinary wells, there is another much cheaper and simpler kind, which may probably be found specially suited to forest work. It is built of shaped bricks, but is only one brick thick. Sometimes mortar is not even used, but this has the disadvantage of allowing the surface water to percolate. An example of this well, when made with mortar, is cited as having been dug 80 feet deep in sand and costing only R150. The precaution must be taken of testing the first bricks made for these wells, because, although the brick-mould may be accurately made, the burning often distorts the shape of the brick,

so that after all they will not fit. Thus it is not a bad plan to use an old mould which, by actual experience, has been found suitable. Hoop-iron and iron rods may be used to strengthen the masonry.

§ 146. EARTHENWARE RINGS.—In sandy soils in the Madras Presidency *pot* wells[1] are common. They consist of a number of earthenware rings, prepared and burnt by the ordinary village potter; they are generally 3 feet in diameter, 15 inches to 24 inches high and 2 or 3 inches thick.

The upper edge of each ring has a rim about 1 inch high to it, similar to that of an ordinary earthenware drain-pipe. One of these rings is placed on the ground and the sand inside is dug out, causing it to sink. The rings are made to sink vertically by pressure from above and by regulating the digging away of the sand beneath. When the top of the ring is nearly level with the surface of the ground, a second cylinder is put on the top of it, being kept in position by the rim of the first ring, and the excavation of the sand is continued as before, more rings being added as the excavation proceeds. As the rings only cost R1 each, this form of well-lining is a very cheap one.

In Bengal, similar earthenware rings, called *pât*, are used. They are usually 2 or 3 feet in diameter, 12 to 18 inches high and 2 or 3 inches thick, with a rim on each. Sometimes 2 or 3 *pâts* are placed one inside the other and are thus sunk to make the well-lining more durable. Such wells are simple in construction, last a long time and are very cheap, the average cost of a well 30 feet deep varying from R15 to R30.

§ 147. CORRUGATED IRON.—Sheets of galvanized corrugated iron bent into a cylindrical form have been used in some parts of India as a well-lining with considerable success, and form a cheaper lining than either brick, stone or even wood, when the site of the well is not very far from a railway.

The corrugated iron forms just as effectual a protection against surface drainage or the infiltration of contaminated water as either brick, stone or wood, and is more easily and cheaply placed in position.

[1] Mr. F. A. Lodge, Deputy Conservator of Forests, Madras Presidency.

The well-lining is made of sheets of corrugated iron such as are used for roofing purposes.

The sheets are bent into a semi-circular form in the direction of their length; and two sheets fastened together by bolts and nuts constitute a section of the well-lining. The sheets bent into a semi-circular form and fitted with the requisite nuts and screws can be bought from the principal hardware merchants of large towns in India. The sheets are made to overlap each other for 1½ corrugations (about 4½ inches) at the ring joints and about 3 inches at the vertical joints. The contact surfaces of the sheets should be thickly coated with heated pitch or thick tar before the sheets of iron are bolted to each other.

The sheets are bolted together as they are placed in position by roofing galvanized bolts, nuts and washers. Four bolts are sufficient for a complete ring joint, but in the vertical joints there should be one bolt for each whole corrugation. The thickness of corrugated sheet iron used for the construction of wells varies from 20 to 26 B. W. G., *i.e.* from 0·053 to 0·020 of an inch. So long as the sides of the shaft will stand without support, it is excavated without lining and the sections are built up from the bottom. After this, or if the earth is unstable, the procedure described in the case of a timbered shaft (§ 144, page 232) should be followed. The depth of each ring of which the well-lining is composed will be that of the width (usually 30 inches less the overlap) of the iron sheets used.

The lengths of the sheets of corrugated iron in common use are 6, 7, 8, 9 and 10 feet, so that wells with a circumference of about 12, 14, 16, 18 or 20 feet can be constructed.

Galvanized corrugated iron should not be used if the water is very soft or has any special chemical ingredients, because under such circumstances it may be readily corroded and at the same time poison the water.

§ 148. EXCAVATION OF WELLS.—Wells should be sunk, if possible, at that season of the year at which the water is at its lowest level, and then if the shaft be dug a few feet deeper

than the level of the water, the well will always contain water, except perhaps in an unusually dry year. The earth should be loosened with a pick or *pharwah* (Indian hoe) and the material so loosened raised to the surface in baskets, fastened to the end of a rope attached to a windlass or passing over a pulley. The volume of earth to be extracted from a well is rarely sufficient to warrant the use of the more complicated mechanical contrivances which have been introduced for the excavation or raising of earth.

§ 149. TUBE-WELLS.—A tube-well may be said to consist of a pump, a wrought pipe and a driving filter point. A special driving apparatus is required to drive the tubes into the soil. The best known of the many tube-wells now manufactured is Norton's patent "Abyssinian" tube-well, manufactured by LeGrand and Sutcliff, Hydraulic Engineers, Bunhill Row, London, E. C. Efficient tube-wells, pumps and fittings are also procurable from firms in the principal manufacturing towns of India.

The drive-point ordinarily used will not pierce rock or solid stone formations, but can be driven through hard and compact soil and soft sandstone. If, in the course of driving a well, rock, stone or boulders are met with, the tube put down must be drawn up and put down in another place. Wells of this class are most suitable for gravel, coarse sands, chalk and porous water-bearing strata, and in exceptional cases they have been sunk to a depth of 150 feet. They are commonly sunk to a depth of 50 feet.

Abyssinian tube-wells are not recommended for clays, marls or fine sands, neither can they penetrate rock. When strata cannot be penetrated by the Abyssinian tube-well, it is necessary to make a bored tube-well, *i.e.*, bore a hole through the strata with special tools and then fit a tube into the hole bored. Bored tube-wells have been sunk by Messrs. LeGrand and Sutcliff to depths varying from 40 to 1,342 feet. In many cases the tubes put down have formed artesian wells.

§ 150. PUMPS FOR TUBE-WELLS.—When water is found at a depth of 25 feet or less from the surface, or rises to within that

distance of the surface after the hole has been bored, an ordinary pump will suffice to raise the water to the surface; but where the water is more than this distance from the surface of the ground a special lift or force-pump will be required to raise the water. It is important that the pump purchased should be sufficiently powerful to raise the water in the tube to the surface of the ground.

§151. TUBE-WELLS IN THE NORTH-WEST PROVINCES.—Mr. J. M. Blanchfield, Extra-Assistant Conservator of Forests, writes that the tube-well is a very simple contrivance, consisting of a 6 feet length of steel tube, spiked and perforated; to which, after it has been driven into the ground, is screwed on another 6 feet length of tubing and so on until the water-bearing stratum is reached.

In order to drive the spiked tube into the earth, a steel cap with a hole in the centre is screwed on to its upper end and then a 6-feet jumper, weighted heavily at mid-length with a block of iron is slipped into the steel cap and alternately raised and dropped; when the first length has been driven in, which can be done in all but rocky soil in about half an hour, the jumper is drawn out, the steel cap unscrewed, another 6 feet length of tube screwed on with the aid of a pipe wrench (supplied with the well), the steel cap screwed on again, the jumper placed in position and used as before until water in sufficient depth is reached; this can be ascertained by a weighted string being let down into the tube at intervals. To get at the water tapped, an exhaust, pump supplied with the apparatus is screwed on to the tube-well, but where the water-bearing stratum consists of very fine sand (which is commonly the case in India), it will be necessary to use a sand-pump (*see* §152, page 244) in order to clear away the sand from around the perforated part of the well-tube (fig. 128 page 243) and to ensure its standing in a foot of clear water. For depths greater than 22 to 26 feet a force-pump must be substituted for the exhaust-pump mentioned above.

Tube-wells can be easily pulled up, the process of withdrawing the tube being as simple as that of sinking it. Clips are fitted on to the tube-well after the pump has been unscrewed

and removed, and the tube is raised by means of wooden levers fitted into the clips. Four men can draw up a well under ordinary circumstances. The great objection to tube-wells in Indian forests is their tendency to silt up after a while, even though the sand is cleared away from round the perforated part of the tube in the first instance. This can often be cleared away again by using the sand-pump described in §152, page 244.

§ 152. DRIVING TUBE-WELLS.—The following directions for driving tube-wells have been extracted from the instructions issued by Messrs. Le Grand and Sutcliff for sinking their Norton's patent Abyssinian tube-wells.

Two men are sufficient for driving a tube-well, the diameter of which is 1¼ inches, 3 men will be required to drive a 2-inch tube and 4 men are necessary to sink a 3-inch tube.

The time required to drive a 30-foot Abyssinian well varies from a few hours to three days, according to the hardness of the strata met with and the size of the tube sunk.

Having selected the spot where the well is to be driven, the steel driving-cap *c* is screwed on to the point and drill tube *t* until its shoulder fairly butts on to the tube. This is done by steel levers placed in the holes of the driving-cap provided for that purpose, one of which is seen in the sketch. The small end of the lengthening bar A. is then dropped into the driving-cap *c* and the monkey *d* slipped over the lengthening-bar, resting on the cap *c*.

The whole is then raised to a perfectly vertical position in the centre of the tripod *b*, in which it is retained by a latch *l*. The feet of the tripod should be firmly planted in the ground, so that they will not slip or sink during the work.

The ropes *f*, *f* are secured through the holes in the monkey *d* and passed over the pulleys fixed to the head of the tripod-support, and driving is commenced by the ropes being pulled, raising the monkey and allowing it to fall on the cap. Care must be taken to keep the steel driving-cap *c* screwed up tight, as driving the tube loosens it and the thread of the tube will then be damaged.

FIG. 128.

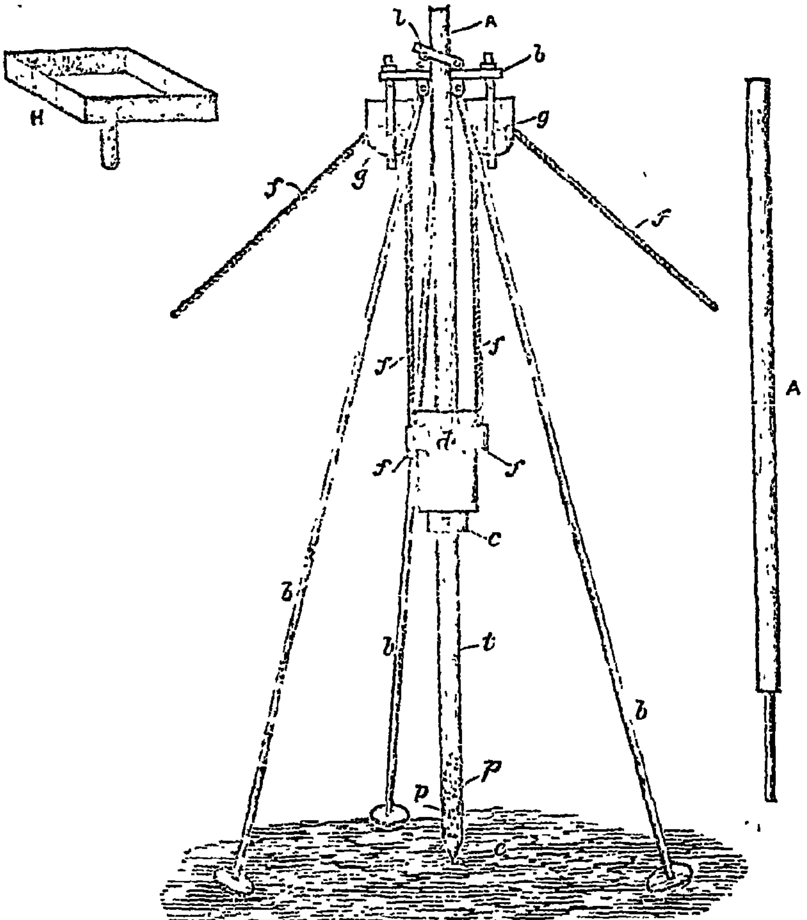


Figure 128 is a sketch to show Le Grand and Sutcliff's apparatus for sinking tube-wells; t *is the pointed and drilled tube which forms the bottom of the tube-well when driven;* c *is the steel driving-cap which is firmly screwed into the tube* t, *and which receives the blows of the monkey* d. *The lengthening-bar* A *is shown separately, and also in position in the well-tube;* b, b, b, b *is the tripod which carries the pulleys* g, g, *shown dotted (as they are not visible), over which the ropes* f, f, f, f *used in lifting the monkey pass;* l *is the latch of the tripod which keeps the lengthening tube in position;* H *is the funnel placed in the well-tube when sand, etc., have to be extracted from the well;* c *is the solid driving point of the tube-well, and* p, p *the perforations in the tube through which the water passes into the well.*

A few blows with the monkey upon the driving-cap will serve to imbed the point of the tube in the ground, and particular care should be taken while driving the first foot or two to see that the tube is driven perfectly vertical. The first length is driven, until the driving-cap nearly reaches the ground, and then a fresh length of tube has to be added. To do this, remove the lengthening-bar and monkey and unscrew the driving-cap. Unscrew the socket from the first length of tube to be added, by means of the barrel and socket tongs. Oil the socket slightly and carefully coat it with white lead, and then screw it on to the end of the tube in the ground. White-lead the threads at the upper end of the tube standing out of the ground, screw the driving-cap on to the new length of tube, adding the lengthening-bar and monkey as in the case of the first tube driven.

The first few threads are screwed on by hand, and the socket is then screwed tight by means of the barrel and socket-tongs which form part of the driving apparatus. The different sections of the tube must be screwed down till they meet or butt against each other, and the joint made so tight that it cannot unscrew in the course of driving. Length after length of tube is added in this manner until the desired length has been driven.

A plumb-line should be frequently used while driving the well to ascertain the presence of water, otherwise a water-bearing stratum may be passed through undetected.

When earth or clay, etc., finds its way into the tube while driving, it is removed by means of small clearing out tubes or *sand-pump*, which are provided in assorted lengths to suit any depth. A sufficient number of these must be screwed together to reach the bottom of the well-tube, and should be carefully lowered into the well-tube; great care must be taken in lowering these tubes into the well not to let them slip down, otherwise considerable trouble may be caused in recovering them. The joints of the clearing out tubes should be made watertight only and need not be screwed on as far as they will go. In withdrawing these tubes it is not necessary to unscrew every joint, lengths of 12 feet can be left joined together.

When the accumulation in the well is of a loose sandy nature, if wet, it can best be withdrawn by means of a special pump-head which is fixed on to the clearing or sand-tubes.

The exhauster of this pump has a larger diameter than the sand-tube, and consequently it can exert a great power. When the diameter of the exhauster is only that of the tube, the force exerted is not enough to draw up the water with the sand, and the sand fills up the whole tube, while the water falls away, in which case there would be nothing to do but to pull up the well-tube. The funnel H. (fig. 128, page 243) should be screwed on to the top of the well-tube before the pump-head is screwed on to the sand-tube, so that, if necessary, water can be poured down the well-tube, when by pumping, sand and mud will be pumped up the sand-tube, and by continuing to pour fresh water down the well-tube and pumping up through the sand-tube all the earth, etc., can be removed from the well-tube.

When a few feet of water stands in the well-tube, the pump should be screwed on to the well-tube, care being taken to white-lead both the threads of the well-tube and of the pump. To start the pump it will be necessary to pour some water into the top and to pump for a few minutes to exhaust the air which is in the well-tube, and when this is done, in all ordinary cases the water will follow.

At first the water pumped will be muddy and gritty to a greater or less extent, according to the nature of the strata. After pumping for a short time and when the water shows signs of clearing, the handle of the pump should be raised high for a second or two; by doing this the valves of the pump will be opened, and this will cause the water to run suddenly down the well tube; a few strokes of the pump will recover the water; this operation should be repeated several times.

The result of the sudden letting down of the water several times and stopping it before it has got down to the water-level of the well, causes the water to force its way violently out of the perforations at the bottom of the well-tube, disturbing the mud and fine particles of the strata in the immediate vicinity of the perforations. If this operation has been done properly the

water will again have become muddy and thick, as at first, and steady pumping will, in a short time, pump up all the mud and fine particles which have thus been disturbed.

The object of this stirring up of the mud, etc., is to thoroughly clear away all the fine particles in the immediate vicinity of the perforations, leaving the larger stones and grit to form a natural filter round the well-tube. The process should be repeated several times, until it is found that the mud, etc. ceases to come up. The quantity of water which the well will yield and the ease with which it can be pumped depends upon the careful carrying out of this operation; while its neglect will in many soils cause sand, etc., to come up some time after the well has been made, and thus diminish the yield of water and the ease of pumping. In some strata if this operation is not properly done when the well is first made, the sand will accumulate and tend to stop the supply altogether.

If sand, etc., accumulate so fast in the well-tube, when the well is first cleared out as described above, that the pump cannot raise the water holding the sand in suspension, the clearing out, or sand-tubes must be put down the well and the accumulation of sand, etc., removed as has been described on page 245. After this has been done, the pump can be again screwed on to the well-tube, and in most cases it will be able to pump up the rest of the sand, etc., till the well is cleared.

When once the well has been thoroughly cleared in the manner just described, care should be taken not to raise the handle of the pump so high as to tilt the valve and let the water down the well. In the latest form of pump, by loosening the studs of the top ring and shifting the handle round an inch the tilting arrangement ceases to act and the water cannot be let down the well and the sand at the bottom of the well-tube disturbed.

If at first great difficulty is experienced in getting to any water, it must not be concluded that no water can be obtained. In nine cases out of ten, the compact earth round the perforations on the bottom tube of the well can be broken up and loosened by the free use of the tilting action of the pump,

so that after one or two hours' pumping it will produce a perfectly free yield where at first it was difficult to get even a small quantity of water.

§ 153. DRAWING UP OF TUBE-WELLS.—If a new tube-well has been driven past a water-bearing stratum it can easily be drawn up to that stratum again; or the tube-well can be entirely drawn up and put in elsewhere, if necessary. When it is found necessary to withdraw a tube-well, this can be done with the help of screw-jacks and clams, the method adopted being to place the jacks, one on each side of the tube, on pieces of stout timber, and slipping the clams over the tubes and fastening them securely to it. The ends of the clams rest on the top of the jacks. The jacks are then screwed out by means of levers, great care being taken to work the jacks together, otherwise the well-tubes will be pressed on one side, thus increasing the friction and labour besides risking the bending of the tubes. When the jacks have been screwed out to nearly their full length, they are screwed back again to the positions they occupied at the beginning of the operation, the clams are loosened and lowered to the top of the jacks and screwed on tight again, the jacks are brought into operation again and the first process repeated until the tube-well is pulled up to the right position or entirely withdrawn. When all the tubes have been withdrawn, they may be driven in another spot. Before this is done, all the sections of the tubes should be examined to see that they are perfectly straight. If any sections are crooked, they should be straightened at a forge, or if no forge is available, they can be straightened by striking them with the side of the monkey. Bent tubes should never be driven, as they are only apt to bend worse, and if they come to anything very hard, they spring, and it is impossible to drive them at all.

SECTION III.—CLEANING AND PROTECTION OF WELLS.

§ 154. CLEANING WELLS.—Unless a well is regularly used, the water which it contains often becomes unfit for drinking

purposes; especially if the well has no covering to prevent the sun shining directly on the water and extraneous substances from falling in. Consequently it is not safe to drink the water in an uncovered and but little-used well, unless the latter is first emptied, the well thoroughly cleaned out, and allowed to fill up again with fresh water. Wells that are in constant use should be cleaned from time to time in order to prevent an accumulation of unwholesome matter in them, and especially at the beginning of each camping season.

The process of cleaning a well consists of drawing up all the water which it contains and removing such extraneous matter and dirt as may have accumulated in it, together with such organic, vegetable and animal matter as may have been developed in or been introduced into it.

In order to ensure that a well is properly cleaned each year, it is very necessary to know the exact depth to which the well was originally sunk. In addition to recording the depth of the well in the office, a good plan is to have the depth of the well up to a known mark engraved on a stone or brick near the top of the well.—(*Mr. F. A. Leete.*)

The presence of organic matter in water is most injurious. It commonly finds its way into a well by infiltration through the soil if the well-lining is not efficient.

If there is a layer of foul air above the water in the well, a lighted candle lowered carefully into the well will be extinguished on entering the layer of foul air.

No stables or sheds, where cattle are kept, should be allowed in the vicinity of a well, as they are a most fruitful source of contamination.

If the water-supply runs low at certain seasons of the year, the well should be cleaned, and, if necessary, deepened when there is only a small quantity of water in it.

Permanganate of potash should be thrown into wells which are not in every-day use at the beginning of each camping season, as this substance is a most valuable purifying agent. The amount to be put in depends upon the state of the well and its size.

Dr. Hankin[1] recommends that during the prevalence of cholera in a district, wells should be frequently disinfected by permanganate of potash in the solid form, which is less objectionable to Hindus. The powder should be added each time until the water is faintly pink in colour. Charcoal is also useful in purifying wells, and is easily procurable in most forests. From 80 to 100 lbs. of charcoal should be thrown into a well after it has been thoroughly cleaned.

§ 155. PROTECTION OF WELLS.—The water of a well is very commonly rendered unwholesome by the entry of surface drainage into it. So long as a well is protected from the sun, from contamination by surface drainage and its accompanying impurities and is in constant and regular use, the water should remain perfectly sweet and good. The top of the well should be raised a little above the surface of the surrounding country, and, if practicable, a masonry platform covered with concrete or cement should be built round the well proper, sloping away from the well in every direction, so as to prevent any water which has been drawn out of the well and used for washing purposes from flowing back into it. The well lining prevents the water which runs off the platform from finding its way into the well again. A covering should be constructed over the mouth of the well to prevent leaves and foreign matter from falling into it.

The cheapest form of covering will be a light, open shed, which may be roofed with thatch, wood, tiles, or corrugated iron. Where the lining is made of stone or bricks, the lining may be carried up above the surface of the ground and a dome constructed over the well itself, openings being left through which water can be drawn. The surface of the water should not be darkened by the covering placed over the well, so that birds and animals which fall into the well may be seen and removed before they contaminate the water.

If the well lining consists of brickwork or masonry, no trees should be planted near it, as their roots (especially of the genus *Ficus*) are very liable to force their way through the masonry lining of the well and allow of surface drainage finding its way

[1] Annual Report of the Bacteriologist and Chemical Examiner to the North-Western Provinces and Oudh for 1895-96.

into the well. The trees themselves will absorb a large quantity of water and may even in extreme cases cause the well to dry up.

A windlass with a rope or chain and iron bucket should be provided for all wells that are much used; and water-carriers should be made to use this iron bucket and should not be allowed to put their own buckets or water-skins, which are often very filthy, into the well. If this is done there is much less risk of the water in the well being contaminated.

A trough for animals to drink from, alongside of the well, is very useful. Wells without parapet walls are dangerous and should not be allowed. If a well has no parapet wall round it, an open wooden grating should be placed over its mouth to prevent people falling into it. A chain hanging down the inside of the well is very useful when the well is being cleaned, besides affording a means of escape to any one falling into the well.

Part VII.—CONSTRUCTION OF EMBANKMENTS, WEIRS, AND WATER CHANNELS. RIVER-TRAINING WORKS.

SECTION I.—EMBANKMENTS AND DAMS FOR RETAINING WATER.

§ 156. To obtain a constant supply of water for irrigating a nursery or plantation at all times of the year, or in connection with the drifting of firewood or some other special purpose, it may be necessary to construct a small embankment, with a view of increasing the supply of water in a small stream, or causing an accumulation of water. The embankment will be formed across a small valley or ravine in which the water may accumulate, or down which the small stream flows. A dam constructed in connection with the floating of fuel or timber should be made of dry rubble, with a core of masonry or clay. For irrigation purposes in connection with forest works, as the area to be irrigated will rarely be large, as a general rule, only small dams will have to be constructed.

§ 157. The thickness of an embankment constructed to retain water will depend upon—

(1) the nature of the materials of which the dam is made;
(2) the depth of water which is required;
(3) the geological formation of the locality in which the embankment is to be constructed.

An embankment will be widest at the base, to withstand the heaviest pressure; both pressure and width or thickness will decrease gradually up to the top. The transverse section of the embankment will depend upon the nature of the materials used. Embankments are commonly constructed of carefully selected earth, earth faced with stone, or of stone only. If constructed of earth, they should have a hearting wall or core of clay to prevent water percolating through the embankment. The dimensions of a dam constructed of earth are necessarily very much greater than those of one made entirely of stone or of

earth faced with stone, so as to make up for the smaller resistance to pressure of that material. Embankments constructed of stone may be made of masonry throughout, or of dry rubble with a core of masonry to prevent leakage.

The *foundations* of an embankment should be carried down to the solid rock, if it is not far from the surface, or, at any rate, to a stratum impervious to water if such can be found. If the embankment is thrown across a narrow rocky valley, it should be constructed of stone and built into a vertical groove cut in the rock on either side to prevent the imprisoned water from finding its way round the ends of the dam wall.

Where the volume of water to be retained is not very considerable, the embankment may be made of earth, dry rubble, or earth faced with brushwood or stone to protect it from the scour of the water. If dry rubble is used, a core of clay must be added in order to render the embankment watertight, and the inner face of the embankment should also be covered with clay. Where only a small supply of water is required, and the nature of the soil permits, the dam may be constructed of two rows of piles driven into the ground so that the piles have their sides in close contact in each row, and the space between the two rows filled in with earth. The distance between the rows of piles should be decreased in proportion as the volume of water to be retained is lessened.

Where an embankment is made of earth only, the surface exposed to the action of the water should be protected by a layer of stones or brushwood kept in position by long stakes driven into the embankment itself.

The height of an embankment made of earth should never exceed 70 feet, while the width of the top of such an embankment should be from 12 to 20 feet, if there is a roadway along the top. The slope given to the inner face exposed to the action of the water should be of 1 in 3, that of the outer face may be 1 in 2½.

Dams constructed to retain water should present a convex

surface to the body of water, the pressure of which it has to support.

FIG. 129.

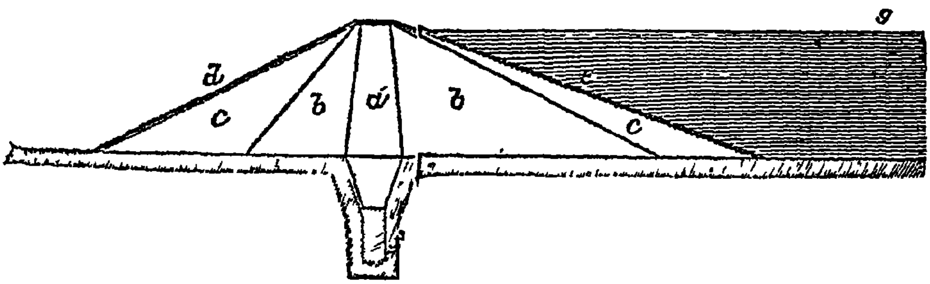


Figure 129 is a cross-section of an earthen reservoir dam : a *is the core or hearting wall of clay puddle ;* b, b *the selected clayey material ;* c, c *is open stone filling ;* d *is stone pitching or turfing ;* e *is stone pitching :* f *is a water-tight concrete wall in a soil permeable to a considerable depth ;* g *the level of water flowing down the escape channel or waste weir. (Scale 96 feet = 1 inch.)*

(Reduced from a drawing in the Roorkee Treatise of Civil Engineering of India.)

The ordinary method of constructing an embankment is as follows :—The breadth of the top is first fixed with regard to the quality of the puddled clay and the backing material; for good puddle a width of 6 feet, and for ordinary or inferior, a width of 8 or 9 feet will give an impervious hearting; the backing on each side may be 3 feet thick and upwards. Sometimes for small embankments the thickness of the puddle is specified to be one-tenth of the height of the bank, *plus* 3 feet, and a corresponding diminution is made in the thickness of the earthen backing on each side. The clay puddle wall should be carried down to an impermeable stratum, or if this is not found comparatively near the surface, a trench with strongly supported sides may be dug down to an impervious stratum and filled with cement concrete, thoroughly compacted. The top of the concrete must be widened out to receive the base of the clay puddle

wall. The clay puddle hearting is carried up 5 to 8 feet above high water level according to circumstances, the height of waves caused by wind in the reservoir, etc. Its thickness may be 6 feet at the top or 8 feet at water-level for a bank 30 to 40 feet high, its side slope outwards at a ratio of 1 in 12 to 1 in 6. The clay must be well soaked with water, chopped up small, and well beaten or trodden into a homogeneous plastic mass. A sandy clay is the best, as it shrinks least in drying. The clay should be prepared on a clean platform, and then deposited in layers 6 to 9 inches thick, each layer well watered, cut with spades, worked and rammed down till it is thoroughly incorporated with the previous layer; the surface of a layer must not be allowed to become dry, or it must be well watered and *worked up again to the plastic stage. The proportion of* sand or of fine gravel to be mixed, if necessary, with the clay may be from one-sixth to one-third by bulk. The selected clayey backing on each side of the puddled hearting is deposited in thin layers well consolidated; for about 2 or 3 feet width on each side of the backing it is carried up about 1 foot in advance of the puddle, the earth being held up by boards temporarily placed to give the side slope of the puddle. This method allows of the puddle being flooded and kept moist during any temporary cessation of work.

Selected material is placed on either side of the core, and the rest of the dam is made of the most suitable material that can be obtained near by. *Selected material* is the term applied to the best—*i.e.* the most impervious to water—material which can be obtained locally. The face of the embankment exposed to the action of water should be protected with a stone pitching of roughly rectangular stones set on edge, and from 6 to 12 inches deep at the full water level; or by flat stones carefully bedded in clay where the dam wall is small and the water shallow; or, if this is too costly, by a layer of brushwood tied up in bundles and fastened by strong stakes driven into the embankment.

The outer face of a high earthen dam should not be made in a continuous slope as shown in figure 129, page 253, in situation

where the rainfall is heavy, but should be separated into two, three or more slopes by nearly horizontal steps or benches, which may be from 6 to 12 feet wide and sloping from the horizontal at 1 in 20 to 1 in 30; these benches check the velocity of the accumulating surface water. When the reservoir is a small one, it is often cheaper to cover its bed and sides with clay than to take the core of the embankment down to an impermeable substratum.

§ 158. Vegetation, vegetable soil, tree stumps and roots must be entirely cleared away from the site of an earthen dam, and the toe of the inner face is generally protected from undermining by a curtain wall of selected material sunk to a suitable depth on a stepped foundation bed.

The materials actually used in the construction of an embankment depend upon the volume of water which it is required to retain, the materials which are available locally, and the nature of the locality in which the reservoir is to be constructed. The nature of the construction must be modified to meet the requirements of each case. In forest works, where only a small quantity of water is required, it will generally be sufficient to construct a dam of dry rubble and face it with a layer of puddled clay or, if stone is not available locally, to make it of earth, faced with brushwood. If the bed and sides of the reservoir will not hold water, it will be necessary to spread a layer of clay over them as well.

Before selecting the site of a proposed reservoir, it is most important to examine the nature of the material of which the bed and sides of the site are composed, as, if these are permeable to water, the site is not a suitable one; because, before the reservoir could hold water, the bed and sides would have to be made watertight, and this, if the reservoir is large, will be a costly operation. If, however, an impermeable stratum is found a short distance below the surface of the soil, the reservoir will be rendered watertight by carrying the clay core down to this bed.

§ 159. Some arrangement must be made for taking off the

surplus supply of water which flows into the reservoir or tank. The best plan, where practicable, is to make a channel at one side of the embankment, planned so that, when the water in the reservoir has reached a certain level, the whole of the inflow can escape by the side channel. Where the nature of the ground is such that a side channel cannot be constructed, one portion of the dam should be made lower than the rest, and paved with stone or constructed in masonry so as to allow the water to flow over the dam itself without injury to the structure. The provision for discharging surplus water is of the first importance. Reservoir failures can in many cases be traced to the insufficiency or unsuitability of their waste weirs.[1]

The water required for irrigation purposes is usually allowed to pass through sluices built in the embankment itself, and the amount of water discharged is regulated by enlarging or decreasing the area of the opening in the sluice. One of the sluices should be just above the floor of the reservoir, so as to allow of its being emptied when necessary for cleansing or repair. The bed of the reservoir in the neighbourhood of the sluice should be paved to prevent its being scoured by the escaping water.

Sluice gates may be worked in various ways; a simple method for a small vertically lifted gate is to use a lever with a ratchet at the side to fix the gate at any desired point.

§ 160. In Part V, section X, page 186, reference has been made to the necessity, which sometimes occurs, of constructing a dam across the bed of a stream to obtain a sufficient volume of water to allow of the stream being used for the transport of firewood or timber. In Europe such dams have been constructed of masonry and of dry rubble, with a core of clay strengthened by wooden frames. The door closing the lower sluice must be so constructed that it can be opened wide when the water

[1] Mr. C. E. Dupuis, F.C.H., Public Works Department, Irrigation Branch.

FIGS. 130 and 131.

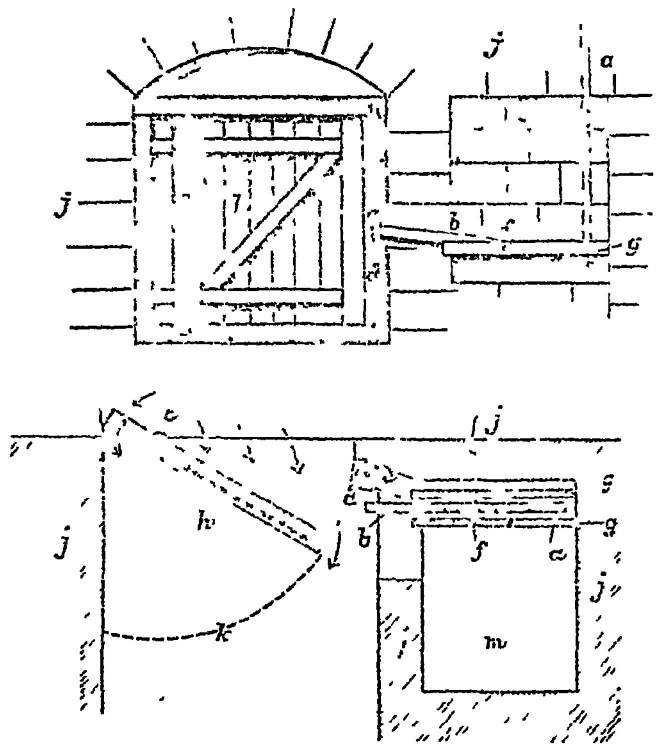


Figure 130 is an elevation of the sluice door of the Klorinsky dam, Salskammergut District, Austria, by opening which the imprisoned water is allowed to escape when required. a *is the long pole (only a portion of it is seen) by means of which one end of the lever* b *is depressed so as to free the post* d, *which keeps the door shut; a stud* c *projects from the post and the lever* b *pressing against this stud keeps the post* d *in position and the door shut.* f *is the pivot round which the lever is free to move;* g g *is the frame to which the pivot is fixed;* h *is the door of the sluice;* e *is the pivot on which the door turns;* j *is part of the masonry of the dam;* k *(fig. 131) is the passage through which the water rushes when the sluice gate is open;* m *is an opening leading from the sluice gate to the top of the dam. It is made in the thickness of the dam and is furnished with steps so as to allow of the sluice gate being inspected if necessary. (After Mr. G. R. Forster.)*

Figure 131 is a plan of the same, showing the door partly open and the catch released. The same letters are used in both the illustrations. (After Mr. G. R. Forster.)

collected is to be used for drifting purposes without endangering the life of any one.

Figures 130 and 131 taken from G. R. Forster's *Transportwesen*[1] show the way in which the sluice gate of the Klorinsky dam in the Salzkammergut District is opened.

By pressing down a pole (*a*) the lever (*b*) is forced up, releasing the stud (*c*) and enabling the post (*d*), which has hitherto held the gate closed, to revolve in such a manner as to unlock the gate. The force of the water will then push the gate open. In order to prevent the gate being hurled against the side of the passage, the pivot on which it works is placed a short distance from the wall, so that, while the main body of the water rushes past one side of it, a certain amount also passes the other side, and causes the gate to open gradually.

SECTION II.—WEIRS FOR THE CORRECTION OF MOUNTAIN TORRENTS.

§ **161.** In mountainous districts, which are subject to heavy falls of rain, streams, which during the greater part of the year contain very little, if any, water, become transformed, during the season in which heavy falls of rain occur, into rushing torrents capable of doing an immense amount of damage, by cutting away their own beds, causing slips, and carrying stones, mud and other materials on to the fertile plains below and transforming them into barren wastes.

The amount of damage done by such torrents depends upon a number of causes, among which the most important are the annual rainfall, the amount of forest and other vegetation on the area, and the nature of the geological formation.

The more completely a hilly area is covered with well-stocked forest, especially if it is fire-protected and closed to grazing, the more slowly does the rain which falls on it find its way into the river beds, because the layer of humus which

[1] Das forstliche Transportwesen von G. R. Forster. K. K. Forstmeister in Gmunden, Vienna, 1885. Verlag von Moritz Perles, figs. 114 and 115.

exists in such forests absorbs a large quantity of the rain and allows it to flow off gradually. The leaves of the trees break the fall of the rain and the roots bind the surface soil. Other things being equal, the flood level of streams in a well-wooded district will be considerably less than that of those in a treeless area; and in consequence, the power of the stream to do harm in the first instance is much less than in the second. The amount of rainfall being the same, the water reaches the river beds much more gradually when the hillsides are well clothed with vegetation than when they are bare, and brings much less soil with it; the streams will also contain water for a longer period. But where the hill sides are bare, the water at once rushes down them, with the result that the streams come down as roaring torrents for a short time; and the whole hillside is badly ravined.

The actual amount of damage done depends very largely upon the geological formation. If the country is composed of hard rock, the damage done will be small. But if the area, through which the streams flow, consists of soft friable shale or pebble beds, the streams will rapidly cut ever deepening and widening channels, and will carry the loosened material into the plains below, where the bed of the stream often becomes raised above the surrounding country and may become a great source of danger.

The capability of a stream for doing damage by cutting away its own bed, and carrying the loosened material into the plains or flat ground below, depends very largely upon the steepness of the river bed. Water which flows down a gentle slope, with a small velocity, can only carry a small quantity of solid matter with it in suspension, and that solid matter will be in a very finely divided state. The carrying power of water increases with its velocity, and this depends primarily on the steepness of the bed down which it flows; consequently, if the slope of the bed of the stream can be materially decreased, its power of carrying stones or mud in suspension will be proportionately lessened.

We cannot alter the nature of the strata through which a stream flows, but we can protect the catchment area of the stream, and the vegetation which exists on it; and if the slopes are bare, we can take steps to reclothe them with forests. And we can, at the same time, by the introduction of weirs, which will cause the bed of the stream to silt up immediately behind them and will allow of the water flowing over them, reduce the actual slope of the bed of the streams and transform it into a series of nearly level portions alternating with vertical falls which break the force of the stream.

If the hill slopes are afforested, the rain which falls finds its way much more gradually into the beds of the streams; and by the conversion of the continuous and variable slope of the bed of the stream into a series of nearly level portions, alternating with vertical falls of varying heights, the water is deprived of its eroding and carrying power, and consequently of its power to do harm by cutting away its own bed and carrying the eroded material on to the fertile lands in the plains below.

The final gradients of the corrected river bed should all have the same slope, *i.e.* the gradient at which the soil is no longer carried away by the water; it is waste of money to reduce the gradients below this point, while the object of the weirs is not fulfilled if the gradients are steeper than this amount.

The slope of the bed of the stream and its affluents may be decreased to such an extent that they can no longer erode their bed and sides; while as the slopes of the hills become well wooded, the intensity of the floods will be very materially decreased, and the joint effect of afforesting the areas and decreasing the slope of the bed of the stream will be to render the latter harmless.

The weirs must be sufficiently strong to withstand the force of the stream in flood, carrying with it a considerable amount of solid matter in suspension. In many cases where the ground is unstable, the streams come down as moving masses of mud and stones which push down or rise over any obstructions which are put in their way. The material thus brought down

FIG. 132.

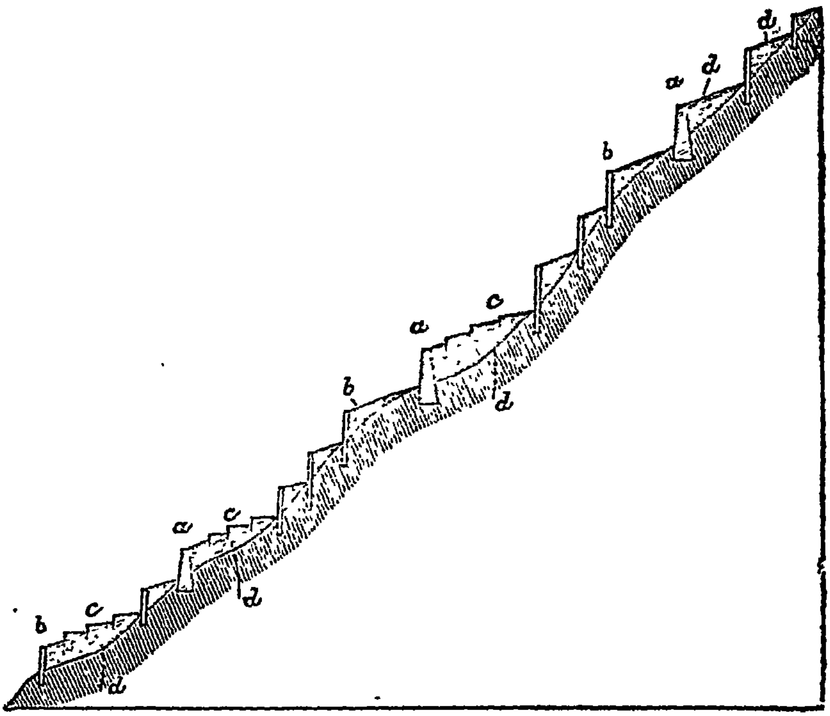


Figure 132 shows diagramatically the method by which a mountain torrent is corrected by the construction of masonry, dry stone, wooden or brushwood weirs across its bed: a, a *are masonry weirs;* b, b *either dry stone or wooden, and* c, c, c *brushwood ones. Vertical heights have been much exaggerated in order to make the diagram plain. The original bed of the stream is shown by a shaded line;* d, d *are the deposits induced by the weirs which cause the gradient of the bed of the stream to be decreased.*

by the stream will be deposited behind such of the weirs as have withstood the force of the flood until the bed of the stream has a uniform slope from the foot of one weir to the top of the weir next below it. When a complete series of weirs have been constructed, in accordance with a carefully devised scheme, across the bed of the stream, the bed of the torrent will be transformed into a series of gentle slopes

interrupted by vertical falls. The velocity of the stream will necessarily be very materially diminished and its power of eroding its own bed and causing the sides of the valley to fall in will be to a very great extent taken away from it.

When the series of weirs is complete the flat portions between them can be judiciously planted up and the reclothing process gradually extended up both sides of the valley. It is very important that the reclothing of the area should be carried on at the same time as the bed of the torrent itself is being corrected, as the intensity of the floods will be decreased in proportion as the well-wooded area of the slopes of the valley is increased. First grass, then shrubs, and finally trees are brought on to the area.

§ 162. The nature of the weirs and the materials of which they are constructed will necessarily vary with the size of the stream and the character and extent of the rainfall. Gentle rain does but little harm; violent storms accompanied by very heavy rain are the most to be feared, since they cause extremely violent floods which, though of short duration, do a very great deal of harm.

The weirs may be made of wooden posts and brushwood, poles laid horizontally, dry stone, or masonry. The smaller brushwood dams are frequently made of living branches, which sometimes take root and grow, thus obviating the necessity of repairs. Before any of the weirs are constructed, a careful survey should be made of the bed of the stream and its branches, and a longitudinal section prepared of the bed of the main stream to be corrected. The number and position of the principal weirs is then determined on the ground, in order that the most favourable positions may be selected for their sites. The number, size and position of the principal weirs are chosen so as to reduce the slope of the bed of the stream to such an extent as to render the water which flows down it incapable of doing harm.

The correction of a torrent must always begin at the top and progress downwards, so as to diminish the risk of damage to

the larger weirs which are necessary when the stream attains a fair size.

Usually the principal weirs are constructed of masonry. They are placed at considerable distances apart, and between them weirs of a much less substantial nature are constructed in order still further to reduce the bed of the stream to a constant slope. The weirs will be constructed as funds are available, from the source downwards. It is very important that the small branches which flow into the main stream should be corrected before the large weirs are formed, as, if all the sources of the side branches are fixed, the quantity of material which is brought down by them into the main stream will be very materially diminished. The fixing of the beds of the smaller streams costs very little, and, until they are rendered harmless, it will be very difficult to correct the main stream thoroughly.

§ 163. The necessity for the correction of the torrents in the French Alps was recognised early in the century just completed, and works were begun in 1840 with a view to preventing the torrents from continuing the work of destruction begun by them.

The torrents in the neighbourhood of Embrun and Barcelonette were visited by the author in 1887, and the information given below is based on the notes then made, as well as on the report on a visit to torrent regions of the Hautes and Basses Alps, written by Mr. E. McArthur Moir in 1880.[1]

The weirs were at first built perpendicular to the direction of the stream, but they are now constructed so as to present a concave surface to the direction of the stream.

Fascine weirs.—Weirs, consisting of fascines (long faggots made of brushwood) supported by stout posts (French *fascinage*) driven into the ground, are used at the heads of ravines and side valleys where the flow of water is very small. The

[1] Report of a visit to the Torrent Regions of the Hautes and Basses Alps, and also to Mount Faron, Toulon, by Mr. E. McA. Moir, Deputy Conservator of Forests, School Circle, N.-W. Provinces.

construction of a fascine weir is described by Mr. Moir as follows: "Rows of posts, generally of willow or of some other" "species which takes root easily, are firmly driven into the" "ground about a yard apart. Behind, *i.e.* below these posts," "are placed fascines made of small branches of trees, bound" "together into bundles of about 40 inches circumference and" "sufficiently long to stretch across the bed of the stream." "Willow branches are generally used, but when these are" "scarce, the interior of the fascine is composed of any other" "kind of branches or bushes which may be available. After" "the posts have been driven in, and the ground behind, *i.e.*" "below them, levelled, a line of willow (*Salix* sp.) or alder" "(*Alnus glutinosa*) cuttings is laid on the ground and" "covered with earth; behind this line, a rough flooring," "consisting of flat stones, is put down to prevent the" "water from undermining the structure; on the upstream" "side of this flooring and the cuttings, the first fas-" "cine is placed and firmly bound to the posts by means of" "willow twigs. Above this fascine a second row of cuttings" "is laid and similarly backed with earth, and then another" "fascine is placed in position, and so on until the required" "height is obtained. The ends of the fascines are firmly em-" "bedded in the banks of the stream on either side. The" "top of the structure should have a slightly concave form, being" "lowest at the centre. The number of fascines in a weir rarely" "exceeds three. Earth or whatever material may be avail-" "able is then thrown behind this obstruction to add to its" "strength. The cuttings and the posts are intended to form" "a living barrier across the ravine, but it is found in practice" "that the posts rarely take root except when the ground is" "very damp. Smaller weirs, consisting of one or two rows of" "fascines, are similarly constructed in the smaller branches of" "the stream, except that the posts are sometimes driven" "through them. As a rule, fascine weirs are placed from 12" "to 18 feet apart, but where the fall of the ground is very" "rapid, the distance between them is decreased to from 7 to" "10 feet."

Rows of fascines are sometimes placed along the sides of unstable banks and pegged into them, seed being sown, or plants put in above them. Where the sides of the valley are very steep and the bed of the stream narrow, obstructions, consisting of posts driven into the ground close to each other (French *clayonnages*) with branches twined between them, are used instead of the fascine weirs described above. These weirs are constructed of larch or poplar poles about 10 feet (3 metres) long, driven into ditches dug in the bed of the stream at intervals of 3 feet. The lower ends of the poles are charred, and the posts are driven as far as possible into the bed of the stream. Branches of poplar and willow are interlaced between the poles, and cuttings of the same species are introduced into the barrier, while the back of the structure is strengthened by the addition of earth and stones, so as to allow of an efficient resistance being offered to the shock of the material first brought down by the torrent. If the weir withstands the first mass of mud and stones brought down by the stream, it will in all probability be proof against all subsequent floods. The central portion of the weir is made lower than the sides, the posts being cut so that the slope from the sides down to the centre of the upper surface of the weir is 1 in 10.

Obstacles, constructed as described above, are introduced between the larger and stronger masonry weirs which are constructed across the bed of the main stream, so as to still further reduce the slope of the bed of the stream between the adjoining masonry weirs, without unnecessarily increasing the number of the larger and more expensive masonry structures.

Wooden weirs.—In the narrow gulleys of the torrent of Vauchères, a new form of wooden weir has been constructed, which promises to give better results than those made of posts and interlaced branches. It consists of larch posts laid horizontally with their ends buried in the sides of the ravine. Four poles are usually sufficient to form a weir, and the upper pole is cut (*see* figure 133) so as to form a trough, in which the water flows away. Holes are made in the sides of the ravine to

receive the ends of the poles in such a way as to disturb the earth above them as little as possible.

FIG. 133.

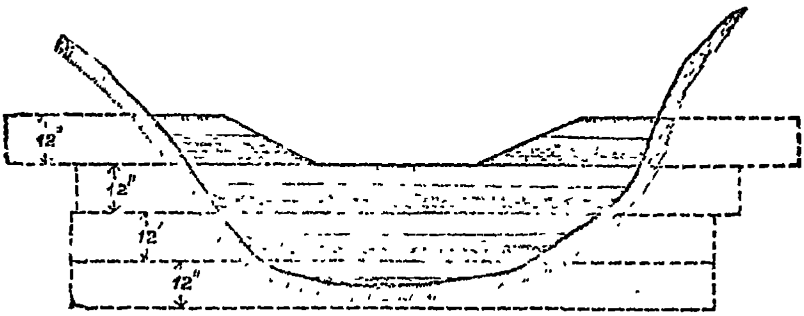


Figure 133 is an elevation of a wooden weir used in the Vauchère torrent, French Alps. The portions of the poles embedded in the sides of the ravine are dotted. (Scale 4 feet=1 inch.)

These weirs are placed so as to make the resulting slope of the bed of the stream a gradient of 12 per cent., or 6° 50′. The tops of the *clayonnages* should be in one and the same straight line.

Near Brienz in Switzerland, secondary weirs are made of sharp pointed posts, 5 or 6 feet long and 6 to 9 inches in diameter, driven into the bed of the stream by 2 or 4 men using a wooden ram similar to that described on page 129, § 113, Volume II.

The posts are driven, as far as possible, into the bed of the stream which is thickly strewn with boulders, and branches are intertwined between the posts which are driven in at distances of 2 or 3 feet from each other. The posts are placed in lines straight across the bed of the stream, the distance between the lines of posts being from 20 to 50 feet. Intermediate rows of posts are added where necessary. The slope of the bed of the stream has been reduced to 8° 50′ (15·5 in 100), but this is still too steep and it is being further reduced by the addition of more lines of poles. Large masonry weirs

are built at suitable places of immense blocks of stone rolled down from the neighbouring hill-sides. The slope of the *cone de dejection* formed by the stream has a gradient of from 5 to 6° (8·7 to 10·5 in 100).

Dry-rubble weirs.—Weirs constructed of dry-rubble are used in the smaller valleys, where wood is not available. The dry-rubble weirs are placed only in the smaller ravines where the force of the torrent is not great. No culvert is left in them for the passage of water, as it can find its way through the interstices between the stones of which they are made. These weirs present a concave surface to the direction of the stream. The upper surface of the weir is cup-shaped, the amount of depression at the middle is one-tenth of the width (measured horizontally) of the weir. The height and width of these barriers vary with their position in the bed of the stream. The width of the weir at its upper surface should be half its height. Sometimes the upper layer of stones is set in mortar to strengthen the structure.

The bed of the stream immediately below dry-rubble weirs is paved with large stones in order to prevent the water which falls over the weir from eroding the bed of the stream.

Masonry weirs.—Masonry weirs are constructed across the main bed of the torrent in places where great strength is necessary.

The thickness of masonry weirs is considerably greater at the base than that at the top, the up-stream face of the weir is nearly vertical, while the other has a decided slope. The breadth of the weir half-way up is usually made about half its height. The top of the weir is usually made lower at the centre than at the sides, the amount of depression being, as in the case of dry-rubble weirs, one-tenth of its width.

The barriers present a concave surface to the direction of the stream. The foundations of these weirs are (in France) always stepped into the solid rock, or, where this is not practicable (as is often the case in India), to a depth which is not affected

by the action of the stream in flood, and are thrown across the bed of the stream where it is narrow. The curve given to the barrier against the direction of the stream is the same as would be given to the soffit of a bridge subtending the same chord. A culvert provided with a grating, consisting of wooden posts, is left in the weir just at the level of the bed of the stream so as to provide a passage for the water ordinarily brought down by the stream, and at the same time to hold back the stones brought down when a flood occurs.

The bed of the stream immediately below the weir is paved with large blocks of stone, so as to prevent the stream from digging out its bed immediately below the weir, and thus endangering its stability. This pavement is made as long as the weir is high. It is given a gentle slope and ends in a small masonry wall about 3 feet high. The foundations of this wall are of rubble masonry. The upper 3 feet of the wall is made of dressed stone. The bed of the stream, between the foot of the weir and the small masonry wall in which the large blocks of stone end, soon becomes filled up with stones and mud brought down by the stream when in flood.

Masonry weirs are sometimes provided with wing walls both up and down stream to further strengthen them. If a depression in the pavement (kept constantly full of water) were made to receive the water which falls over the weir, or finds its way through the culvert in it, as is done in the case of small irrigation canals in India (see figure 124, page 273) so that the water which passes over the weir might fall on to a cushion of water, the damage done to the pavement below the weirs by the water which flows over them would be materially decreased.

SECTION III.—SMALL WATER CHANNELS.

§ 164. It is sometimes necessary to construct small water channels in order to lead water from a stream or spring, either to a dwelling-house for drinking or other purposes, or else to a nursery in order to supply the young seedlings with water in

the rainless seasons of the year. The total quantity of water required will never, under ordinary circumstances, be large, nevertheless the channel should be carefully designed in the first instance, so as to prevent its cutting away its bed, in consequence of an excessive gradient. Where the supply of water is only just sufficient to meet the requirements of the case, the channel should be lined so as to prevent loss by percolation.

§ 165. GRADIENT OF SMALL WATER CHANNELS.—The gradient which should be given to a water channel depends upon the nature of the ground through which it passes, and also upon whether it is lined with masonry or brickwork or not. When the channel is simply dug in the earth, and is not lined in any way, the gradient should not, as a rule, exceed about 2 feet in a mile. This fall would give a velocity of about 3 feet per second to the water flowing down it. Where the channel is made in flat country, a fall of 6 inches in a mile will be found sufficient to allow of the water flowing properly.

Where the supply of water is small, the channels should be lined in order to prevent loss by percolation all along the channel. Where the channel is of a permanent character, it may be lined with masonry or brickwork; but where it is of a temporary nature, it may consist of a wooden trough, placed either in the earth, or on supports, in order to obtain a suitable gradient. In Upper India, semal (*Bombax malabaricum*) forms good troughs for water.

When a very small channel[1] is lined with masonry, its gradient may be almost anything, and if the supply of water is a very small one, it will probably be best and cheapest to adopt whatever slope is found on the most direct line. A fall of 1 in 100 is a very good slope for small masonry-lined irrigation channels to carry a discharge of one cubic foot or less per second. For larger quantities of water smaller slopes are better. Where the discharge is more than 10 cubic feet

[1] Mr. C. E. Dupuis, F. C.H., Executive Engineer, Public Works Department (Irrigation Branch).

per second, any slope exceeding 1 in 400 or 1 in 500 gives velocities causing excessive wear on the sides and base of the channel.

In parts of Bengal, Assam and in Burma, where large hollow bamboos are easily obtained, and where only a small supply of water is required, it is brought long distances in bamboos. The gradient[1] given to such pipes will generally depend chiefly on the slope available, and is not of much consequence, so long as it is sufficient to cause the water to run with fair velocity. The slope should not be less than 1 in 30 (about 2½ degrees) and may advantageously be much more. So long as the joints are carefully made to prevent splashing out or leakage, the steeper the slope is the better; as the steeper the slope the greater the velocity of the water, and consequently the greater the discharge which can be obtained through a pipe of given section.

Portions of the culm are cut away at the nodes, to allow of the solid septa being removed, and any bodies that may fall into the channel being taken out.

Where bamboos are not available, wooden channels, either triangular or rectangular in section, may be used instead. If it is not practicable to have the same gradient throughout the whole length of the channel, the sectional area of those portions of the trough which have a low gradient should be greater than that of the portions whose gradient is high, to allow the same volume of water being carried along the whole length of the channel and to avoid waste. The trough may be made in one continuous line; in which case the joints between the sections must be so constructed as to avoid leakages, or else the end of the upper section should overlap that of the section immediately below it.

§ 166. FALLS IN SMALL WATER CHANNELS[1].—In hilly ground one of the chief difficulties in constructing small water channels is not to obtain sufficient slope for the flow of the water, but

[1] Mr. C. E. Dupuis, F.C.H.

so to speak, to get rid of the surplus slope of the country over and above that necessary to produce the required flow. It is for this reason, almost as much as owing to the extreme porosity of the ground at the foot of large hills, that irrigation channels constructed in such situations, as for instance in the Dehra Dun District and Terai of the North-Western Provinces, are generally masonry-lined.

If water channels in such situations were not masonry-lined or provided with falls, they would rapidly degenerate into ravines, which would widen and deepen, and draw in the adjacent drainage by lateral ravining, until they often get entirely beyond control and become very destructive. For small distributing canals in the alluvial soil of the plains a slope of about 1 foot per mile has been found by experience to be the gradient most suitable for *earth channels*, and any slope in excess of this is got rid of by building masonry falls at convenient sites. The water falling by a vertical drop into a properly constructed cistern disposes of its surplus energy in the turmoil and churning of the waters produced; the energy is actually converted into heat by internal friction, and the water thus deprived of its eroding power.

In the gravelly soil of hilly districts, a much higher slope is permissible; but 1 in 1,000 or 5 feet per mile is the most that can be safely given, even in small unlined channels. By masonry-lining the channel, not only is much water saved by the prevention of loss by percolation, but a much steeper slope can be advantageously adopted; as the velocity permissible is much greater, and the greater the velocity, the smaller the section of the channel required to yield a given volume of water, and, consequently, the cheaper will it be to make. A limit is, however, soon reached, even in masonry channels, at which the velocity becomes so great as to injure the work by scouring out the mortar joints and wearing away the bed by the drifting sand and gravel.

Slopes of 1 in 100, 1 in 200, 1 in 400, and 1 in 800 have all been adopted in various parts of the *masonry-lined channels* of

the Dun canals for discharges of about 20 feet per second. For channels of this size 1 in 400 is no doubt quite steep enough, as the masonry cannot stand the excessive scouring action of the very high velocities induced by the steeper slopes. For small channels carrying discharges of 1 or 2 cubic feet per second, a slope of about 1 in 100 is best; but in such channels almost any slope may be given without harm, and, as noted above, it will probably be best to follow the slope of the land. For larger channels, when the slope of the land exceeds the limits given above, whether the channels are of earth or are masonry-lined, falls must be provided. In an earth channel the following is a neat and substantial type of fall drawn for a channel of 3 feet bed width and a discharge of about 10 cubic feet per second with a vertical drop of 2 feet.

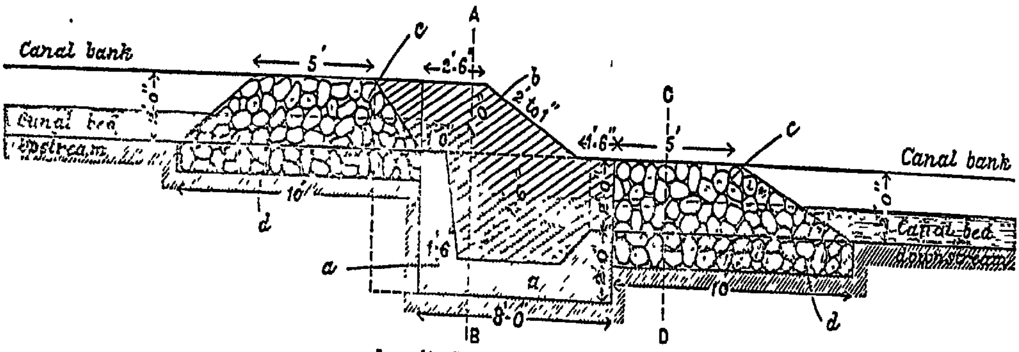
Figures 134 to 137 show the construction of a two feet fall suitable for a small unlined water channel.

In constructing a fall of this kind, it is important to remember that the earth-filling round the walls and the pitching above and below the fall are nearly as important as the actual masonry in the fall itself.

In masonry-lined channels of small section it is cheaper, and on the whole, more satisfactory to make "ogee" falls or curved water-shoots; only it must be remembered that these falls give an exceedingly high velocity to the water at their foot, and in consequence the whole shoot should be built of the best work with picked bricks or squared stone, and fine joints, pointed, if possible, with Portland cement.

Figure 134 is a longitudinal section of the fall. Figure 135 a plan of the same. Figure 136 a cross-section at A B, through the masonry or brickwork portion of the fall just below the crest. Figure 137 a cross-section at C D, through the down-stream stone pitching. In the above figures: a *is masonry or brickwork in section;* b *the same in plan or elevation;* c *is stone-pitching in plan or elevation;* d *the same in cross-section;* e *is the unlined base of the water channel; and* f *the unlined sides of the same. Scale 5 feet = 1 inch.* (Designed and drawn by Mr. C. E. Dupuis.)

FIG. 134.



Longitudinal Section

FIG 135.

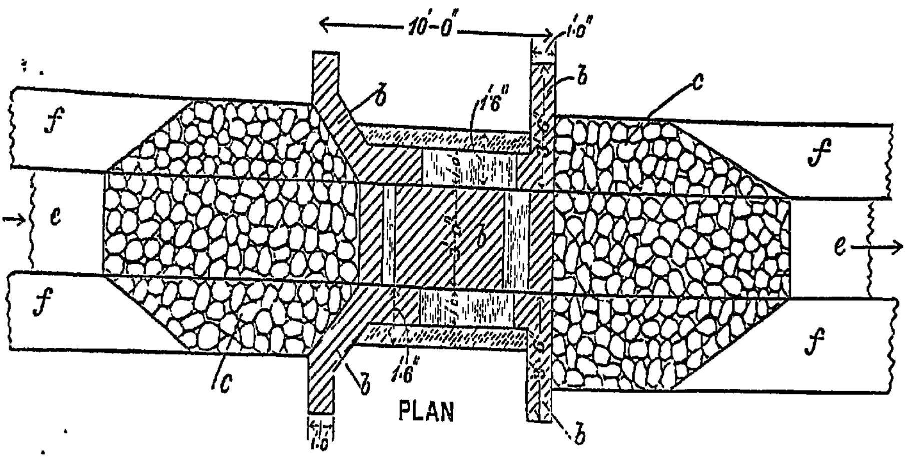


FIG. 136.

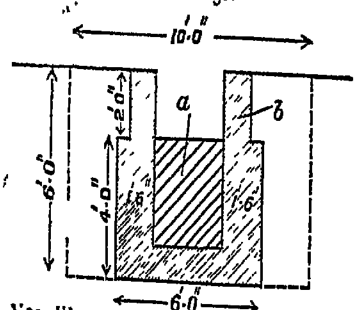


FIG. 137.

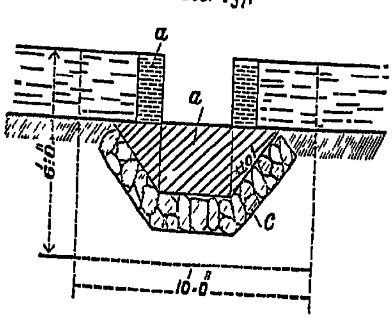


FIG. 138.

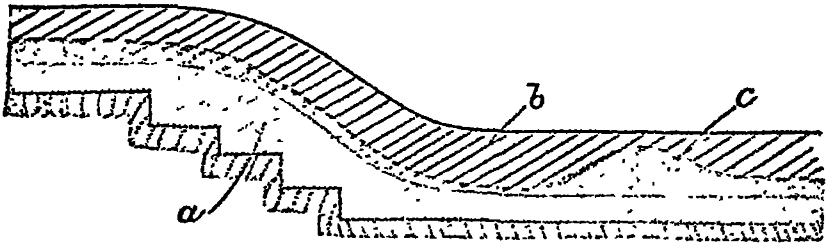


Figure 138 is a longitudinal section through an "ogee" fall suitable for masonry-lined channels of small section: a *is the masonry in section;* b *the same in elevation;* c *the water in the channel.*

A succession of small falls have been found by experience to be much better than a few large ones. The height of the falls on small channels should not, as a rule, exceed a feet, and a fall should be introduced as often as the nature of the ground requires one.

§ 167. CONSTRUCTION OF SMALL WATER CHANNELS.[1]—In designing any such small water channels as may be necessary in Forest engineering, the first point to be determined is the amount of water available, and if this is in excess of the discharge required or not.

If the whole supply available can be profitably utilised, a few discharge observations should be taken of the stream or other source of supply in the dry season of the year, or some sort of idea arrived at by local enquiry of what it is at such times.

The channel should then be designed to carry the largest supply likely to be available in the stream or spring, when the water is required for irrigation or other purposes. It is a useless waste of money to make the channel larger than is necessary, and moreover the capacity of a small channel is very easily increased, if afterwards the supply turns out better than was anticipated; but this seldom happens.

[1] Mr. C. E. Dupuis, F.C.H.

If there is an ample supply of water in the stream or other source, a liberal view of the quantity of water required should be taken, and the channel designed accordingly.

A continuous discharge of 1 cubic foot per second is sufficient for the irrigation of about 20 acres of rice, or 50 acres of *rabi* crops, and one-twentieth part of this is amply sufficient for the drinking and washing requirements of a very large community.

One cubic foot per second is sufficient to give the liberal allowance of 50 gallons per head per day to a population of over 10,000 people. These facts are given to show what an extremely small continuous supply of water suffices for domestic purposes. If required for seedling plantations, 1 cubic foot per second could probably irrigate at least as much as it could if under rice, or say 20 acres.

If the available supply be in excess of the requirements, and if the ground be fairly flat, it will be cheaper to make an earthen channel with masonry-lined falls where necessary, to keep the gradient low; as the loss by percolation will in this case not be of much consequence.

A channel of 2 feet bed, with 1 to 1 side slopes and 2 feet deep with a bed slope of 2 feet per mile, with 2 feet falls as required, would be very suitable for any discharge (volume of flow) from 1 to 3 or 4 cubic feet per second.

If the available supply be small, or the ground steep, it will probably be better to make a masonry-lined channel. The following table shows the approximate sections of channel in square feet required for different slopes and discharges:—

Slope.	Discharge to be carried, in cubic feet per second.	1	2	3	4	5	10	15	20
1 in 50	Section in square feet	·2	·3	·4	·5	·6	1·2	1·6	2
1 in 100	Ditto . .	·3	·4	·5	·7	·8	1·5	2·5	3
1 in 200	Ditto . .	·4	·5	·7	·9	1·0	2·0	3·0	4
1 in 400	Ditto . .	·5	·7	1·0	1·3	1·6	3·0	5·0	6
1 in 800	Ditto . .	·6	1·0	1·3	1·8	2·0	4·0	6·0	8

The above table shows that a channel of a section of half a square foot will suffice to carry a discharge of from 1 to 4 cubic feet per second according as the bed slope varies from 1 in 400 to 1 in 50. A larger section than this will seldom be necessary in the class of works under consideration.

Typical sections for channels of various dimensions are shown in the following figures:—

FIG. 139.

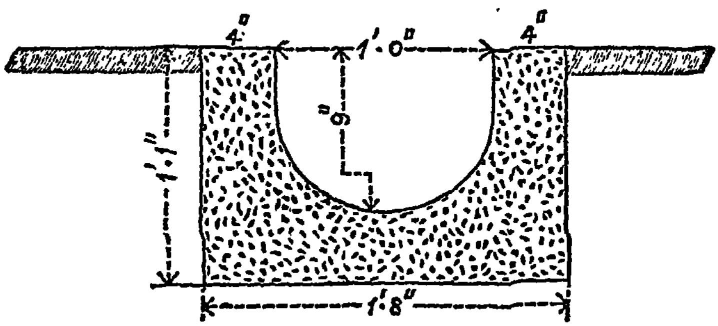


Figure 139 is a type cross-section through a channel lined with concrete, the area of which is 0·64 square feet.

FIG. 140.

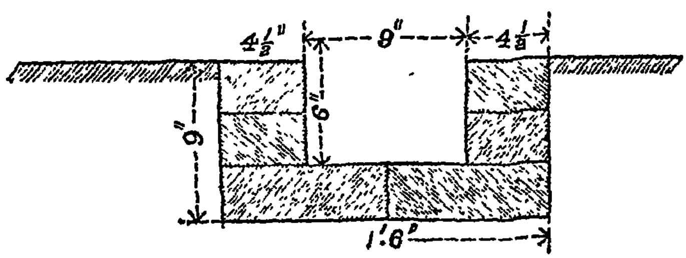


FIG. 141.

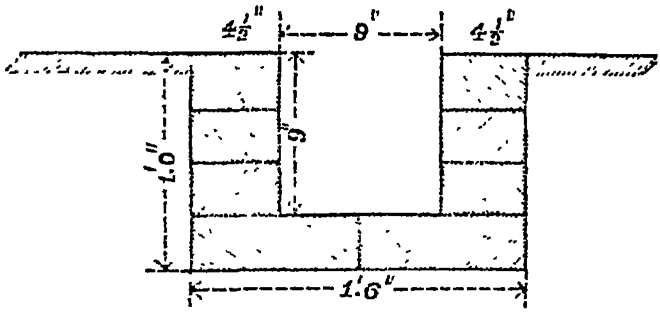


FIG. 142.

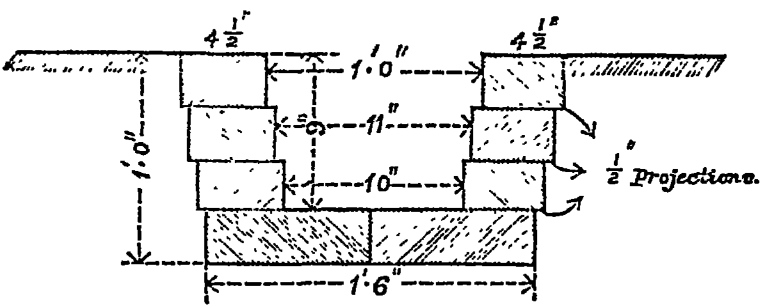
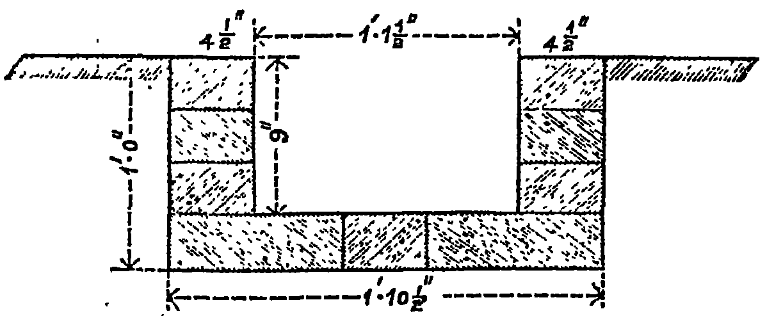


FIG. 143.



Figures 140 to 143 are type sections of small brick-lined water channels of different superficial areas. Scale = $\frac{1}{10}$ (drawn by Mr. C. E. Dupuis).

For very small sections, brickwork channels are decidedly preferable. If bricks are expensive or difficult to obtain, concrete can be substituted, but it is not so durable. For larger sections, boulder-masonry or brickwork are best, whichever is cheaper; brickwork is always the more durable of the two. Where the water channel is of a temporary nature, and wooden troughs are used, they may be hollowed out of small trees, or else may be constructed of planks nailed together. The objection to water channels made of planks is that they are not water-tight unless kept permanently wet, and are less durable than masonry or brickwork channels; but on the other hand they are very much cheaper to construct and stop the percolation of water through the sides of the channel; but will leak at the joints between the sides and base and between the different sections of the troughs themselves. This leakage is most important when, as is so often the case, the supply of water is very small, and it has to be economized as much as possible. A well-laid line of large hollow bamboos is very much more durable and preferable in every way to a wooden lining for a channel to carry a small supply of water, when they can be obtained cheaply. Channels for the supply of water to permanent nurseries should be lined with bricks or masonry.

SECTION IV.—PROTECTION OF RIVER BANKS.

§168. The banks of rivers, which are being cut away, may be protected—

(1) by strengthening directly that portion of the bank which has been cut away, or is in danger of being cut away, sufficiently to withstand the force of the current to which it is exposed; or

(2) by diverting the current of the stream from that portion of the bank which is being eroded, by building out protective embankments (*spurs*) into the bed of the stream.

Where the current of the stream is slow, the planting of grass, etc., along the side which it is intended to protect may

strengthen the bank sufficiently, when it is thoroughly established to divert the current and so protect the threatened bank.

In the first case, only the portion of the river bank which is actually being cut away is protected; in the second, the current is deflected more or less from its original course, and may be thrown against the opposite bank if too much resistance is offered to its flow.

The direct protection of the banks of rivers is, as a rule, more expensive than the diversion of the stream from the threatened portion of the bank by building out spurs into its bed; but in some cases, where the stream is a large one, it will often be found impracticable to divert the stream, and, in that case, direct protection must be resorted to.

Where there is a danger of throwing the current on to the opposite bank of the stream, it will generally be advisable to adopt direct protective works.

§169. DIRECT PROTECTIVE WORKS.—The nature of the materials used to protect the banks of a stream or river directly depend upon the size and character of the stream and its bank, and upon what materials are available locally. If the erosion takes place above the ordinary water-level and the current of the stream is sluggish, fascines made of brushwood and pegged into the banks will usually be sufficient.

Where we have to protect the bank of a mountain torrent, the protective works must be of a more substantial character. The threatened bank may be protected by driving stakes into the bed of the stream at the place where it is being cut away, and intertwining branches of trees between the posts. The posts should be driven to a depth of five or six feet into the bed of the stream, in order to prevent their being undermined. If stronger protective works are required, the river bank may be faced with large stones. The dry stone wall thus formed may be strengthened by the addition of a wooden framing introduced into it and well embedded in the ground, so as to protect it from the force of the current, and to bind it longitudinally and transversely.

When the current of a stream in flood sets against a part of the bank that must be protected, lines of very large blocks of stone or concrete should be constructed at the foot of the threatened portion: a few very large and heavy blocks will afford a much more efficient protection than a large number of small ones, since the force of the stream, which is sufficient to move the smaller blocks bodily away, will be powerless agains very large blocks, which are too heavy to be moved away bodily.

Where large stones are not available, *cribwork* facings may be substituted for them in localities where wood is plentiful. The cribwork facing consists essentially of a wooden framework which is filled in with stones. The base of the cribwork facing will, similarly to the sides, be constructed of straight poles laid parallel to the direction of the length of the facing and supported by and nailed to the transverse poles which are placed at intervals to strengthen the structure. The largest stones that are available should be used for filling up the interior of this framework, and the horizontal poles, of which the framework is composed, should be so close together that the stones cannot be forced out between them. The upright posts to which the horizontal poles are fastened should be buried deeply in the bed of the stream itself if practicable so as to prevent the structure from being undermined and carried away. If the construction is undermined, the wooden poles at the base will prevent the stones from falling out, and the structure will, if the framework remains intact, sink as a whole. The method in which cribwork is constructed will be fully discussed when the cribwork spurs shown in Figures 147, 148 and 149, page 292, are being described.

The disadvantage of cribwork spurs is that they are not durable: their durability depends upon that of the wood used in their construction.

§170. When the bank of a stream has been breached or much weakened, and it may be necessary to strengthen it sufficiently to withstand the force of the stream in flood, as, for example, when

the safety of some buildings or other structures depends upon the bank of the stream being maintained intact. In this case it may be necessary to construct a strong dry-rubble dam in the breach, when the largest available stones should be used, the larger and heavier ones being placed at the base of the dam. The width of the base should be much more than that of the top of the dam. The face of the dam towards the stream should be given a batter of 1 in 4, the other side may have a much more gentle slope, so as to give the dam the required width at the base. If the dam is made of dry-rubble, the structure can be considerably strengthened by the introduction of wooden beams. Some of these should be built into the face of the wall, placed upright, and buried three or four feet in the bed of the stream; others framed into these may be placed horizontally, some parallel to the face of the wall, and others at right angles to it, going right through the structure. Wood being much more elastic than stone affords a more efficient protection against the stones and other material brought down by the stream when in flood and hurled against the dam.

The construction of a dry-rubble dam 40 feet long placed in a breach made in the bank of the Bhagiar stream (Jaunsar Forest Division) by the great flood of the 9th August 1889 is shown in figure 144. The stream threatened to flow through the breach and endanger the existence of a forest rest-house, and also the anchorage of the suspension bridge across the Tons, so that it was absolutely necessary to keep the stream in its original channel.

The dam was made chiefly of the boulders brought down by the flood, the largest stones were placed in the lower portions and face of the structure, and the smaller stones were placed in the interior and at the back of the dam. The dam is still (1895) in good condition and has efficiently protected the rest-house and the suspension bridge.

§ 171. INDIRECT PROTECTION OF RIVER BANKS.—Direct protection of river banks is necessarily more expensive than indirect protection, and is consequently only used when the

FIG. 144.

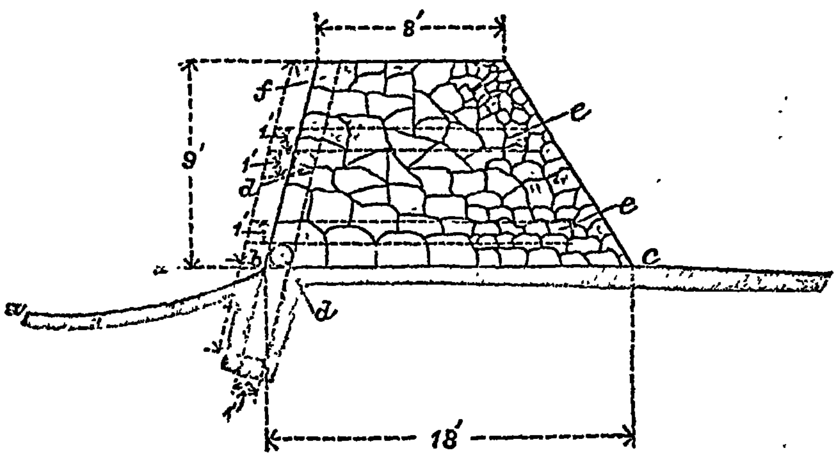


Figure 144 is a cross-section of the Thadiâr dam; a b. *is a part of the bed of the stream;* b c. *of the ground surface of the breach in the bank of the stream. The logs* d, e, f, *all 1 foot in diameter, which tie the structure together, are shown in dotted lines. (Scale 8 feet = 1 inch.)*

indirect methods of protecting the river banks cannot safely be adopted. A river bank may be protected indirectly by means of *spurs* built out at an angle with the bank of the stream, in order to divert the current of the stream away from the bank which is being eroded, and thus to prevent its being cut further away. A *spur* is the name given to the obstruction which is built out from the bank of the river to be protected into the bed of the stream, in order to alter the direction of the set of the current. This obstruction may be constructed, according to circumstances, of earth, earth faced with brushwood, wood, cribwork, dry-rubble, blocks of concrete or masonry. The nature of the materials used in the construction of spurs depends upon what are available near by, the size of the stream and the velocity of its current when in flood and the length of time for which the spurs are required. In the case of small or sluggish rivers, spurs may be constructed of two or

more rows of posts between which brushwood is intertwined, the space between the lines of brushwood being filled in with earth or stone. In the plains, where the fall of the bed of streams is very slight and its velocity consequently low, spurs may be made of earth, faced, if practicable, with flat stones; or brushwood may be pegged into the face of the spur exposed to the force of the current.

In the plains where large bamboos are plentiful, they may be used instead of timber or brushwood. Excellent spurs can be made of them, the bamboos being used as poles and also flattened out and plaited into rough mats.

In the case of streams and rivers in mountainous districts, where the fall in the bed of the streams is very much more than is the case of streams in the plains, the spurs must be of a more substantial nature in order to withstand the greater force exerted on them by the stream, owing to its increased velocity and its more confined channel.

It is most important that all spurs built in dry river beds subject to floods (except those made of earth) should have good foundations, carried down several feet below the bed of the stream, to prevent their being undermined by the force of the current and subsequently carried away. In the case of large masonry spurs, the nose would be much strengthened if founded on a small well 5 to 10 feet deep and filled in with shingle or cheap concrete. The weakest part of the spur is the up-stream corner of its end, as this is exposed to the full force of the current, and special care should be taken to make this portion of the spur sufficiently strong. In the case of spurs made of cribwork, a toe of masonry is often added at the up-stream corner of the end of the spur to prevent its being undermined and the stability of the whole spur in consequence endangered. A spur will protect the bank of a stream for a length of seven times the distance of the end of the spur from the bank. This distance is measured at right angles to the bank of the stream, and not in the direction of the spur itself. Of this length, four times the perpendicular distance of the end of the

spur from the bank lies below and three times this distance above the site of the spur itself. The more perpendicularly the spur is placed to the bank of the stream, the greater will be the length of the bank protected, and also the greater the force exerted by the stream on the spur, and consequently the greater the danger of its being destroyed.

§ 172. Until quite recent years it was considered inadvisable to make the inclination of the spur to the direction of the current more than 45° and it was generally made considerably less. The reason given being that, if the spur was built out at right angles to the current of the stream, it would not be able to stand the force of the current and would be carried away bodily by the first heavy flood.

The experience gained by the Irrigation Branch of the Public Works Department in the plains of Northern India has, however, led them now to construct the spurs at right angles to the bank to be protected; or, if the bank is curved, radially to the curve.

They have found that if the spurs are inclined otherwise than at right angles to the current of the stream, the force of the current is not wholly checked, its direction is changed and the current runs down the side of the spur and undermines and destroys its nose. Whereas, if the spur is placed directly across the current, the velocity of the stream is effectually checked; there is much less tendency to undermine and carry away the nose of the spur; a slack water is formed behind the spur, and the material brought down by the stream is at once deposited there and materially strengthens the structure. In consequence of this recent experience, the spurs now built by the Irrigation Department to train rivers are now built at right angles to the direction of the current of the stream in flood, and the old plan of giving the spur an inclination to the direction of the current of less than 45° has been abandoned.

When spurs are built at right angles to the current of the stream in flood, it is absolutely necessary that they should be made sufficiently strong to withstand the force of the stream. They are necessarily shorter—in some cases very considerably so—than the inclined spurs, and a shorter total length of spur will be required to protect a stretch of river bank than if the spurs were inclined at a small angle to the current. In this case it is not necessary to construct a spur of the same strength throughout its whole length. That portion of the spur which is acted upon by the stream must be made very strong; but the portion of the spur which connects the nose end with the bank, and is not directly acted upon by the current of the stream, may be made of a very much less substantial nature.

§ 173. In constructing spurs it is always necessary to bear in mind that they practically always fail in one way, and in one way only; namely, by the undermining and carrying away of the nose—so long as the nose stands firm, a spur will seldom fail further back. In fact, a spur is as strong to resist floods as its nose is to resist the undermining effect of the scour to which it is exposed, and no stronger. Since the scouring action to which the noses of spurs are exposed is much greater in the case of spurs inclined at a small angle than in the case of those placed directly across the current, the latter type has a distinct advantage over the former.

Care should be taken that the top of the spurs should be well above the surface of the stream in flood. A number of short spurs will protect the bank of a river much more effectually than a few long ones, and there is much less danger of their being carried away. Again, the effect of several short spurs would be to protect the bank of the stream efficiently without deflecting the course of the stream to any great extent; whereas the presence of a few long spurs, if they stood, would be to turn the direction of the current materially, and possibly to throw it on to the other bank of the stream to such an extent as to endanger it.

The length from the nose, for which the spurs must be made very strong, depends upon the distance between the spurs themselves, and this in its turn upon the width of the stream. The distance between the spurs should be equal to the width of the stream. When the spurs are placed at right angles to the current, each spur may be considered to be unprotected for a distance back from its nose equal to about one-fourth of the distance between the spurs, and for that distance should be made sufficiently strong to resist of itself the force of the stream in flood. The spurs should always be placed a little closer together than appears necessary in order to ensure the efficient protection of the bank. Further back the spur need not be so strong, as it is more or less protected by the spur above. Generally a strong bank of shingle and boulders (or sand protected on the surface if the bed is sandy) connecting the nose with the high bank of the river will be sufficient to prevent the water cutting behind the nose and outflanking the work.

§ 174. An average case for ordinary torrent training would be the case of a torrent 100 feet wide in a soil composed of shingle and boulders, trained by spurs of shingle and boulders, with noses of cribs filled with boulders. In this case the spurs would be about 100 feet apart and the spur noses would consist of 3 cribs each 10 feet long, the extreme end being further strengthened by a footing of masonry or, if need be, founded on a well filled in with shingle or cheap concrete.

Fig. 145 represents a typical case of threatened damage to a road by the cutting away of its banks by a river, and illustrates the manner in which such damage may be averted. The river has for some reason made a heavy set on its right bank, at the same time shoaling up its left side, and is rapidly eating into and cutting away the bank and endangering the road.

In such a case it is generally best to have a plan of the site made on the largest convenient scale. Then lay down on the plan a line (either straight or curved) showing the position to

FIG. 145.

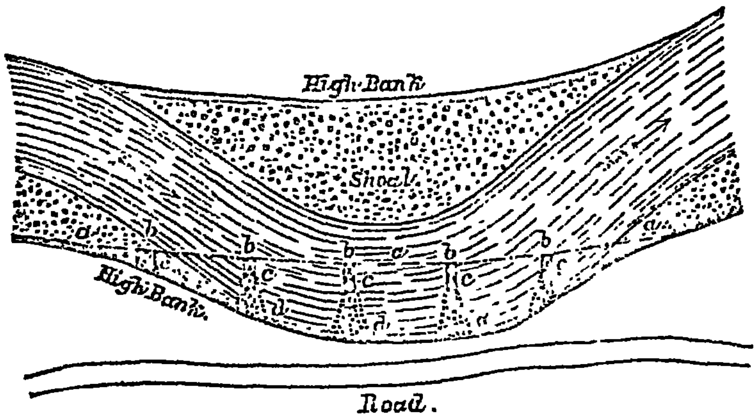


Figure 145 shows a typical example of the way in which spurs should be built out from the bank of a stream so as to efficiently protect the bank which is being cut away by a stream in such a way as to endanger the safety of an existing road. The dotted line a, a, a *shows the distance to which it has been decided to protect the bank;* b, b, b, b *are spurs; of these spurs the portions* c, c, c, c, c *are made sufficiently strong to resist by themselves the force of the current, and the portions* d, d, d *are constructed of less strong materials. The arrows show the direction of the current (drawn and designed by Mr. C. E. Dupuis).*

which the bank of the river at the place where it is being cut away can be, and ought to be, restricted. This line should be fixed with regard to the general course of the river above and below this place and the natural width of the channel. Care must be taken not to contract the bed in such a way as to interfere with its normal flow. A series of radial spurs should then be run out from the high bank of the stream to this required line at a distance apart equal to the width of the torrent to be trained. The nature of the different portions of these spurs has already been discussed (*see* para. 171, page 281).

§ 175. An example of spurs inclined to the current of the stream at an angle less than 45° is shown in figure 146, which is a plan of part of the river training works on the River Tonse,

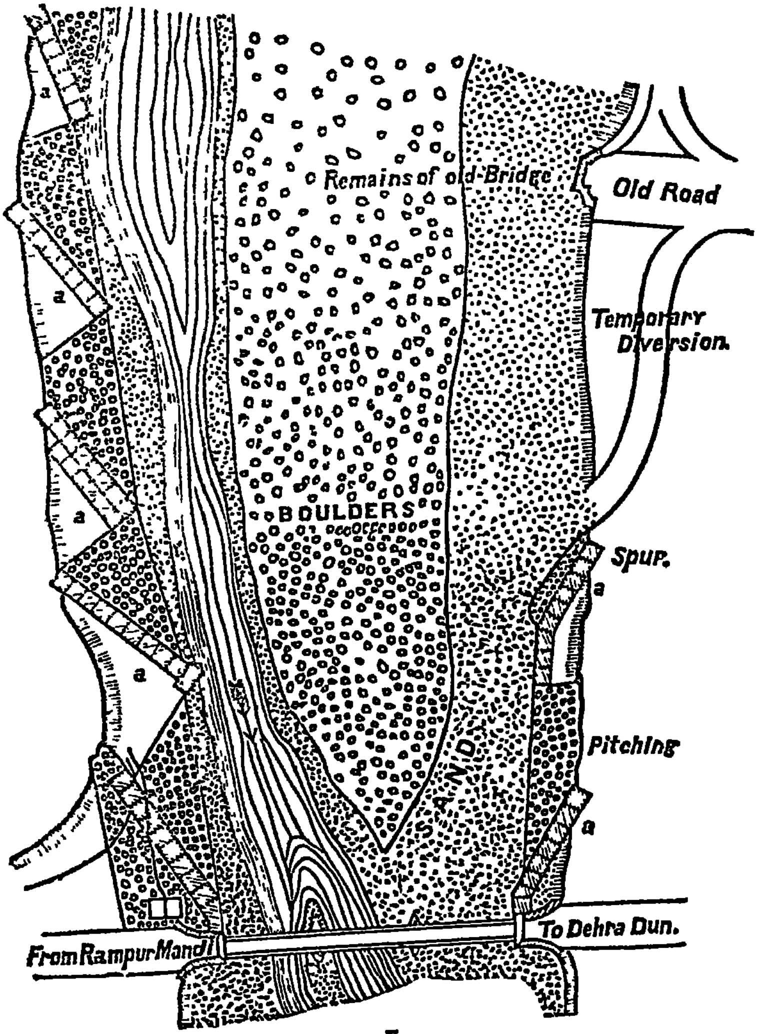
where it crosses the Dehra-Rampur Mandi Road in the Dehra Dun District. These protective works were constructed in 1888, to protect the approaches to the new bridge, which had been erected to take the place of that carried away during the preceding rains.

The old bridge was entirely destroyed and the torrent broke through its right bank. This accounts for the extra strength of the protective works on this bank of the stream. The space between the cribwork spurs was pitched with boulders so as to give them additional strength.

The result of these training works has been most satisfactory, the large deposit of boulders has been to a great extent cut away and the stream now flows directly under the bridge and shows no special tendency to cut away either of its banks.

§ 176. CONSTRUCTION OF SPURS IN DRY RIVER BEDS.—In India, so far as forest works are concerned, many of the streams which require to be trained, either to protect some building, or to keep a stream in its proper channel, so that it may flow under, without endangering the stability of, a bridge thrown across it, are nearly, if not quite, dry during the greater part of the year; and it is only when they are swollen by the heavy fall of rain in the monsoon that they become at all dangerous. Consequently, the necessary protective works can usually be constructed when there is no water, or only a very little, in the bed of the stream itself. In constructing spurs for the protection of the banks of a stream, we should remember that we only want to protect the bank which is threatened, and to keep the stream in its present course; and that in consequence the spurs constructed should be sufficiently large and strong to effect the complete protection of the bank without deflecting the course of the stream more than is necessary. If the spurs are longer than is necessary for the actual protection of the bank, they will probably deflect the current of the stream in such a manner as to cause it to cut away the opposite bank, and thus aggravate rather than relieve the danger.

FIG. 146.



SCALE 44" = 1 MILE.

Figure 146 is a plan of the bridge on the Dehra Rampur-Mandi road over the Tonse torrent. The remains of the old bridge are shown above the site of the present one. a, a, a, a *are cribwork spurs built out into the bed of the stream to protect the banks. A pitching of boulders has been placed between the spurs in order to further strengthen the protective works.*

Fascine spurs.—Where the stream is a small one, or the current inconsiderable, an efficient spur may be constructed by driving two or three rows of posts into the river bed at suitable intervals and intertwining them with brushwood. The spurs, if they stand, by checking the velocity of the stream, will induce the formation of deposits on either side of them, and so further increase the protection afforded by them to the bank of the stream.

Where single rows of posts are not sufficiently strong to withstand the force of the current, a double row of posts should be used, and the space between them filled in with brushwood fascines, closely packed together and well trodden down. The top bundles should be tightly bound down by strong ropes tied from one row of piles to the other across the fascines.

Stone spurs.—Where stone is abundant and available at a cheap rate, it is generally the best material for the construction of spurs. The largest stones should be used for the lower portions of the spurs and for facing the side which is exposed to the action of the stream. The base of the spur should be made a few feet wider than twice its height; since the spur need not be more than a few feet wide at the top, and the angle of repose for stone is greater than 45 degrees.

Stone spurs may be constructed of dry-rubble or masonry, or both combined. That portion of the spur which is exposed to the full force of the flood should be made of masonry, while the portion which is but rarely affected by floods may be made, for the sake of economy, of dry-rubble.

The spurs used for training the Rani Rau above its passage over the Ganges canal, near Hardwar, were constructed chiefly of dry-rubble. The up-stream corner of the ends of the spurs were strengthened by the addition of two masonry walls constructed so as to protect the corner of the spur and to induce a deposit of sand near it.

Spurs constructed entirely of masonry are necessarily expensive, and will only be required when a large stream, which is liable to heavy floods, has to be trained.

Cribwork spurs.—Large angular stones are required for the construction of spurs made of stone only, but where such stones cannot be obtained, fairly strong spurs may be constructed of wooden frames filled with round stones. The wooden framework prevents the stones from being carried away by the force of the stream, while the stones render the construction too heavy to be removed bodily by the stream. The wooden framework is made up of a series of straight horizontal poles laid alternately lengthwise (*a*) and crosswise (*b*), figs. 147 and 148, page 292, and notched, as well as pinned or nailed together. The horizontal poles are fastened at intervals to large poles (*c*), and placed on their inner side either upright or slanting, as the cribwork is rectangular or trapezoidal in section, and embedded if possible to a depth of several feet in the bed of the stream; the base of the framework is made of poles *d*, *d*, parallel to the length of the spur and fastened to the cross pieces (*e*) which are placed at intervals to strengthen the structure.

The timber used for the construction of the cribs shown in figures 147, 148 and 149 is sál poles 10 or 12 feet long and from 5 to 6 inches in diameter. The slanting (*d d*) posts are a little thicker. All cross and longitudinal poles of timber are inside the uprights and are fastened to them with twisted spikes. The longitudinal poles are fastened to the cross-pieces by 9 inch spikes. The cribs are sunk from 1 to 2 feet below the torrent bed to give them a firm footing. The sections of which the spur is made up are spiked to each other and also lashed together with wire. The heel crib (the one nearest the bank) is tongued into the bank and the excavation made to receive the crib is filled back with boulders, while some boulder pitching is put in at the corners where the spur cuts the bank to prevent it being outflanked.

The poles laid horizontally must be straight, so that the distance between them may be constant, in order to allow of small stones being used to fill them up with. The distance between the poles laid horizontally is regulated by the size of the stones procurable.

FIGS. 147 and 148.

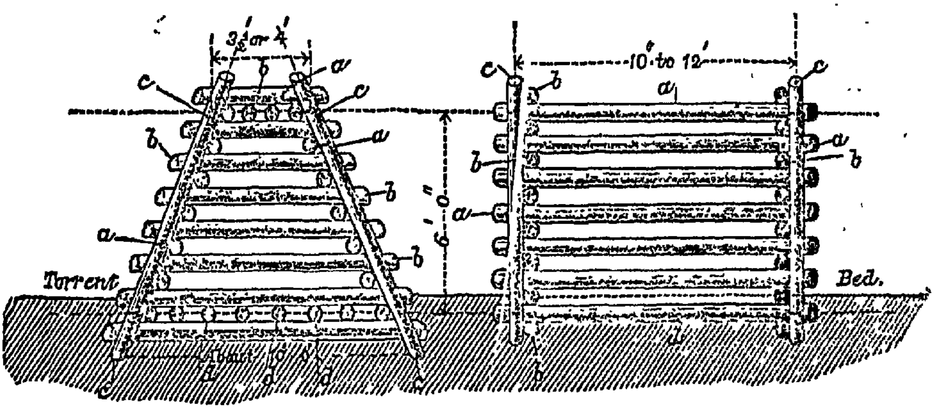


FIG. 149.

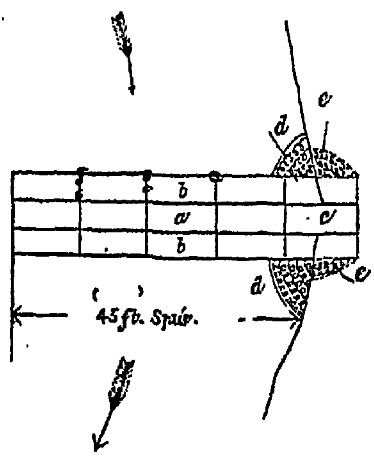


Figure 147 is an end elevation of a cribwork spur filled with boulders, as used at Hardwar in connection with the headworks of the Upper Ganges canal. a, a, a *are the horizontal poles which form the top and sides, and* d, d, *those which form the base of the crib.* b, b, b *are the horizontal poles laid crosswise to the length of the spur.* c, c *are the large poles to which* b, b, b *are fastened. Scale 5 feet = 1 inch (drawn by Mr. W. R. Williams, P. W. D.).*

Figure 148 is a side elevation of part of the same spur, the letters used being the same as in figure 149. Scale 5 feet = 1 inch (drawn by Mr. W. R. Williams, P. W. D.).

Figure 149 is a skeleton plan of a whole spur, showing the direction which it makes to the bank. a *is the top,* b, b *the sloping surfaces of the cribs,* c *is the heel crib,* d, d *the boulder pitching. The arrows show the direction of the current. Scale 20 feet = 1 inch (drawn by Mr. W. R. Williams, P. W. D.).*

The base of horizontal poles is very essential to a cribwork structure under all conditions. If the spur has no such base, a little scour along one side or the end would make a hole through which the stones would escape in detail; and without its stone filling a crib is of very little use. Cribs without bottoms are all very well for works not exposed to much scour, but they are not suitable for a work of a permanent nature. A crib should be as nearly as possible equivalent to a *huge stone capable of sinking bodily without fracture, if undermined.* The whole strength of a crib lies in the extent to which it can stand being knocked about without allowing its stones to escape.

The slanting (*c c*) posts should be buried where practicable from one-third to one-half of their length in the bed of the stream, and the horizontal poles should be carried down 2 or 3 feet below the bed of the stream, in order to prevent the structure from being undermined. The closer together the upright or slanting poles are placed the stiffer and stronger will be the construction.

The upright or slanting members of the wooden framework should not be necessarily arranged at right angles to the direction of the spur, but if the spur is inclined at a small angle to the bank they should be placed in the direction of the current of the stream which will impinge on the spur. If this is done, the strength of the structure will be much greater than if they are placed at right angles to the length of the spur, as the uprights, as far as the direction of the stream is concerned, will be one behind the other and will support each other. The dimensions of the wooden framework depend upon the force which it is required to resist. The cross-section of the spur may be either triangular or trapezoidal. The former shape is usually preferable, as it requires a smaller volume of stones, but where great strength is required, the latter shape should be adopted.

§ 177. THE CONSTRUCTION OF SPURS IN RUNNING WATER.— It may be necessary to construct spurs in a running stream in order to protect a bank which is being cut away, or one which

is threatened; though, as a rule, in India it is possible to construct protective spurs at those seasons of the year when the rivers are low. Such spurs may be made of fascines, cribwork, or masonry on a foundation of large blocks of concrete which are too large for the stream to carry away.

Fascine spurs.—Successful spurs have been made both in Europe and America of bundles of brushwood (fascines). The spurs are composed of brushwood made up into fascines and tied together so as to form a raft. The size of the raft thus formed depends upon that of the required spur. The rafts are usually about 3 feet thick. The raft is floated on to the site of the proposed spur, anchored and sunk by placing stones, clay, or sandbags on it. The lower layers of brushwood may be pegged down by long stakes driven into the river bed before the upper ones are added. More brushwood rafts are floated into position and sunk in a similar way until the spur is brought above the surface of the water. The top of the spur should be capped with a layer of broken stone, 12 feet wide and 3 feet thick. In America, spurs 50 or 60 feet wide and 30 feet high, and as much as half a mile long, have been constructed in this manner. Fascine spurs are not suitable for streams with a swift current.

Cribwork spurs may be constructed in water. The wooden framework is put together on the banks of the stream and filled with stones sufficiently to allow of its floating horizontally. The frameworks are then floated in succession to the site of the proposed spur and sunk by completely filling them with stones. The frameworks are anchored when they are in the correct position in order to prevent their being carried downstream before they are sunk. The different sections of the spur are often well roped together with cheap rope, or fastened firmly to each other with a few strands of telegraph wire.

Masonry spurs.—Where the current is strong and it is necessary to prevent the stream from cutting away its banks, masonry spurs may be necessary. Heavy blocks of concrete, usually of a rectangular form, are made and placed on the site of the spur until the piled up blocks are slightly above the surface of

the stream at its cold weather level. When these blocks have settled, a masonry spur is constructed on them and carried up sufficiently high to be above the level of the river when in flood.

§ 178. PROTECTION OF ROADS CROSSING RIVER BEDS.—In Northern India many forest export roads are taken across river beds which are only a few feet below the level of the road itself. These river beds only contain a considerable volume of water, as a rule, during the rainy season, and then only after heavy falls of rain. At other times of the year they contain very little, if any, water. The roads which cross them are only used for the export of forest produce during the cold weather, when the river beds are for the most part practically dry. A track across the bed of the stream is made passable for carts after the close of the rainy season, and is kept passable until the end of the export season. Cuttings are made from the level of the road on the top of the bank down to the bed of the stream, so as to make the line passable for cart traffic. The gradient of the road in these cuttings should not exceed 1 in 15 or about 3° 50′. The set of the stream, when in flood, will generally be against one or other of its banks, and will cut back a part of the road annually. In order to avoid repairing the foot of the cutting annually, which, in the case of a high bank, may be considerable, it will be in many cases cheaper to protect the road-crossing by the construction of a short spur above; or, if necessary, above and below the road, where it enters the bed of the stream. Two or three short spurs are more likely to withstand the force of the current than one long one. Where it is found that the construction of one spur on the up-stream side of the road does not efficiently protect the whole width of the road, a second small spur should be made on the down-stream side of the road as well. Whether it is cheaper to construct spurs in order to protect the cutting or to repair the road annually, is a matter which must be decided locally in each case.

The nature of the spur will depend entirely on the strength of the current during the rainy season and the materials available locally.

PART VIII.—DEMARCATION OF FORESTS.

§ 179. INTRODUCTORY.—It is most important that all Government forests should be properly demarcated: and that the boundaries should not only be marked on maps, but should be clearly shown on the ground in such a way that there can be no doubt about them, while the records of the boundary should be kept in a simple and intelligible manner, so that in case of doubt or dispute it can be laid out again.

Unless the boundaries of Government forests are properly demarcated in the first instance, and subsequently efficiently maintained, disputes are always liable to arise, which often result in the loss of portions of valuable forest. A careless demarcation of the boundary of a forest and a slovenly compilation of the boundary records cannot be too strongly condemned. The actual methods of demarcation to be adopted will necessarily vary considerably under the existing circumstances in different parts of India, but the principles upon which the demarcation itself is based will remain much the same everywhere. The method of demarcation which is adopted will depend upon the physical nature of the ground; upon the climate, more especially as regards heat and rain; upon the nature of the materials available for the construction of boundary marks; upon the character of the forest growth on the area; upon the condition of the surrounding country, whether it is highly cultivated or not; and finally upon the value of the forest itself and the intensity of the working to which it is intended to be subjected.

Omitting the legal formalities which are necessary under the different Forest Acts, before a permanent forest estate can be formed, the process of demarcation as an engineering question may be considered under the following heads.—

(1) Preliminary selection and delimitation of the area.

(2) The laying down of the settled boundary and clearing of the boundary line or ride.

(3) The erection of boundary marks and survey.

(4) The preparation of boundary records and maps.

§ 180. PRELIMINARY SELECTION OF THE AREA.—When it has been decided to constitute a permanent forest estate, usually a "reserved forest," the first thing to be done is to mark off, approximately, the area which it is proposed to take up. This is usually done by means of temporary marks and a roughly cleared line. In thinly populated localities it will usually be sufficient to blaze trees or erect temporary marks on ridges, the banks of streams, and other physical features. In selecting this line, where the forest is not already surrounded by existing estates, and there is nothing to prevent the best line available being chosen, we should be guided by—

(*a*) the purpose which the forest is to serve, whether for the production principally of large timber, or of small timber and firewood, or of wood alone, or of wood and fodder combined, and so on;

(*b*) the character of the forest growth on the area;

(*c*) the convenience which the line affords for the purposes of protection, inspection and export.

(*b*) *The character of the forest growth.*—This is, of course in most cases, the chief determining factor, but its relative importance depends to some extent upon the object with which the permanent estate is being constituted. Where the area is taken up with a view to forming a forest to be worked for timber and other forest produce, the character of the growth on the area is of the first importance, but where it is being taken up for the sake of affording protection to the ground, that area which will most effectually answer the purpose should be secured.

Areas specially selected, in order to ensure a constant supply of timber, firewood and other forest produce being available, should as a rule be chosen so as to include as far as possible all lands which are covered with valuable timber trees or are capable of supporting them, and to exclude barren areas, areas subject to heavy grazing, affected by burdensome rights or which contain a number of patches of cultivation or scattered villages. If pieces of cultivation or large numbers of villages

exist in the area which is to be reserved, they should, as far as possible, be either excluded, or acquired by exchange or by the payment of compensation. If these methods of dealing with them are not feasible, they should be carefully marked off as enclosures, with demarcated lines similar to those used for the outer boundary.

A few scattered villages in the midst of large blocks of forest are very desirable, as they furnish labour for forest works, supply convenient points for forest guards' huts, etc. Such villages should, however, contain principally or wholly castes depending upon wood-cutting for their means of livelihood. In the Central Provinces numerous villages of the description just described exist, which are officially designated forest villages, and are directly under the Forest Department. (*Mr. E. E. Fernandez.*)

Where areas are constituted reserved forests from purely protective reasons, barren areas and land subjected to heavy grazing should be included, as the former are useless to the private proprietor, and the latter will suffer less if controlled by forest officers.

The boundary of a forest must not, however, be made very complicated in order to include every patch of good forest or to exclude every small patch of cultivation or unproductive area.

(*c*) *Convenience for protection, etc.*—Where private estates adjoin the proposed reserve, the existing boundary of those estates constitutes, of necessity, the boundary of the proposed reserve, but in cases where there is, as is so generally the case in India, considerable latitude for selection, the points to be aimed at are—

(1) that the boundary chosen should be conspicuous;
(2) that it should be easy to inspect;
(3) that it should be well suited for the protection of the forest from fire, etc.;
(4) that it should be a permanent line and not one liable to constant change from natural causes;

(5) that it should consist of as long straight lines as possible in order to diminish the number of boundary marks required.

Natural boundaries of a lasting and unchangeable nature are to be preferred to artificial lines on account of the cheapness with which they can be formed in the first instance and subsequently maintained. The best natural boundaries are a water-parting or the top of a ridge or range of hills; a river channel, if its course is constant; a canal, or the base of a high cliff and especially a road or path, if it is clearly defined. A river which is constantly changing its course (a very common occurrence with the plains portion of Indian rivers) is one of the worst possible boundaries; on the other hand, if one bank is taken as the boundary, the area of the forest is liable to change considerably owing to erosion or deposition by the river. The hill portion of streams in India is as a rule fairly constant, since the streams flow at the bottom of well-defined valleys, and under these circumstances form good natural boundaries. The whole of the stream with a strip along its further bank should, if possible, be included in the reserve in order to allow of the stream being controlled in case it may be required for export purposes.

§ 181. The best artificial boundary in the plains is a metalled road, since it is not liable to change and can be utilized for export purposes. Boundary pillars should be placed along the road at suitable distances from each other, in case the road should be breached by a river, and diverted in consequence. An unmetalled road with definite boundaries or a well-cleared long straight strip come next. No boundary line is so conspicuous as a long straight narrow strip if kept clear of vegetation. Where the forest is situated in the plains, such strips can be converted into inspection paths or lines of export, at a comparatively small cost. If a cleared line is necessary it should be made as straight and as long as possible, provided that the ground is fairly level. In the hills a strip is usually cleared along the boundary of the forest, so as to allow of the

boundary pillars being seen one from the other. If practicable a path should be constructed along the boundary, but in the majority of cases it is not possible to make a path along the boundary, and in that case the cleared strip should be made passable, so as to allow of its being inspected properly.

§ 182. PRELIMINARY DELIMITATION OF THE AREA.—Suppose the hill shown in figure 150, page 302, is to be taken up as a reserved forest. The usual procedure is to select the approximate boundary of the proposed reserve and to lay this line down roughly on the ground. For the sake of uniformity it is usual to begin at the north-west corner of the area and proceed along the north, east, south and west boundaries of the area. The first point selected should be a conspicuous one, which can be easily recognized again, as for instance, a convenient point on a well-defined ridge, or on the edge of a road or path. This point would be fixed so as to include the best stocked part of the forest. A, B, C, D are also selected from considerations of the growing stock on the area and for convenience of protecting the forest, and a rough line cleared from one point to the other. When these points have been finally selected, a draft notification should be drawn up and the legal settlement proceeded with. The selected points E, A, B, C, D may be altered by the Settlement Officer in consequence of representations made to him by the surrounding land-owners.

The actual boundary line of the proposed reserve should be selected while the settlement is proceeding, and if practicable, the line then chosen should be demarcated and surveyed. If the survey and demarcation of the boundary cannot keep pace with the Settlement Officer, it must be pushed on and completed as soon as possible, the temporary marks erected by that officer being replaced by permanent boundary pillars.

§ 183. The Settlement Officer, after he has heard all the cases brought before him by neighbouring land-owners, will finally lay down on the ground the line which is to be the boundary between the reserved forest and the adjacent properties, and will select the position of the boundary marks which are to be erected to mark this line on the ground.

FIG. 150.

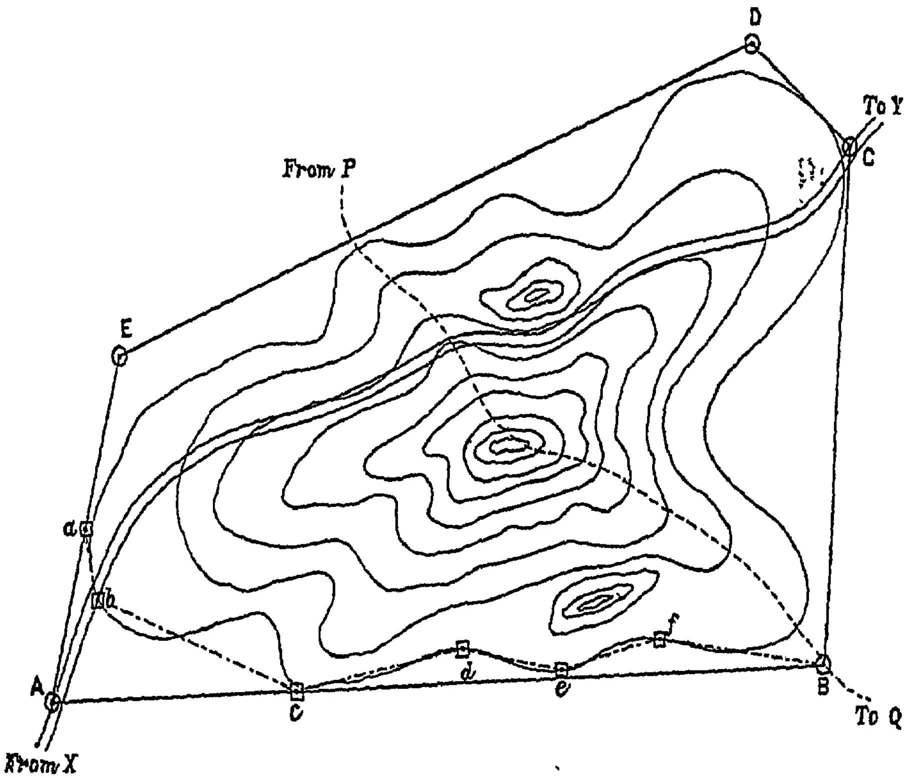


Figure 150 shows the method of selecting the line required for the preliminary delimitation of a hill forest and how this line might be modified so as to get a better boundary when the settlement is being done. A, B, C, D, E *shows the line laid down when the forest is roughly delimitated;* a, b, c, d, e, f, B *shows the boundary line as might be finally selected. A road traverses the proposed reserve from* X *to* Y *and a footpath from* P *to* Q. *The other lines shown in the sketch are contour lines.*

Boundary marks should be erected *at once* on the points selected by the Settlement Officer, so as to obviate all possibility of a dispute as to the exact position of the boundary in the future.

After the boundary marks have been erected a boundary line, strip or clearing should be made along the boundary of the

forest. The boundary of the forest will go in a straight line from boundary mark to boundary mark, and this line should be first cleared of vegetation and then a strip of a certain width, which will vary with the situation and nature of the forest, will be cleared inside this line. The straight line from boundary mark to boundary mark is the legal boundary of the forest.

§ 184. CLEARING BOUNDARY LINES, STRIPS OR RIDES.—It is absolutely necessary in every case, without any exception, that the boundary of a forest must be clearly defined and properly maintained, as in no other way can cattle-trespass or encroachment be prevented. The boundaries of reserved forests in India are almost without exception marked by boundary marks erected where the direction of the boundary line changes and a cleared line or strip between the boundary marks and inside the reserve. The term *boundary line* is, at present, used very indiscriminately to mean the actual legal boundary of the forest, *i.e.* a line, in the sense defined by Euclid; and also the space which is usually cleared of high vegetation—in populous and fully-settled districts at any rate—along the actual boundary in order to make it conspicuous and apparent to every one. The consequence of the indiscriminate use of the term *boundary line* for the actual legal boundary of the forest, and also for the strip of land inside the forest boundary and adjacent to it, has sometimes led to considerable confusion. The use of the term *boundary* should be used when speaking of this actual legal boundary of the forest, and the cleared space inside should be called the *boundary clearing* or *boundary strip*, *boundary ride* or *boundary road*, as the case may be.

Boundary strips are not, as a rule, cleared along well-marked natural boundaries, such as large rivers, the crest of a range of hills, or a water-parting down a well-defined spur, as these are sufficiently well-marked in themselves, unless the clearing is required for the protection of the forest against fire. The width of the *boundary clearing* depends upon the nature of the surrounding areas and also upon the character of the growing stock in the forest.

In the plains where the vegetation is luxuriant, the width of boundary strips is much greater than in the temperate hill forests, where the growth of weeds is much smaller. In the Oudh Circle of the North-Western Provinces the width of the boundary strips between Government reserved forests and private forests is fixed at 50 feet, and where cultivation comes up to the forest boundary the width is reduced to 20 feet.

In the Central Provinces (Northern Circle) experience has fixed 40 feet as the normal width of the boundary strip or ride to make the boundary line conspicuous to all. These cleared strips form excellent lines for preventing fires coming into the forests from the outside.

In temperate hill forests, the usual width of the *boundary clearing* is 10 feet, and where the undergrowth is short, this may be reduced to 5 or 6 feet.

The boundary marks should be inspected and repaired at least once every year. This is usually done at the commencement of the working season at the same time that the boundary strips are cleared.

The *boundary clearing* should always be entirely inside the reserved forest. This is necessary in order to ensure its being entirely under the control of Government. If P, Q, R are the points fixed in the survey for the erection of boundary marks,

FIG. 151.

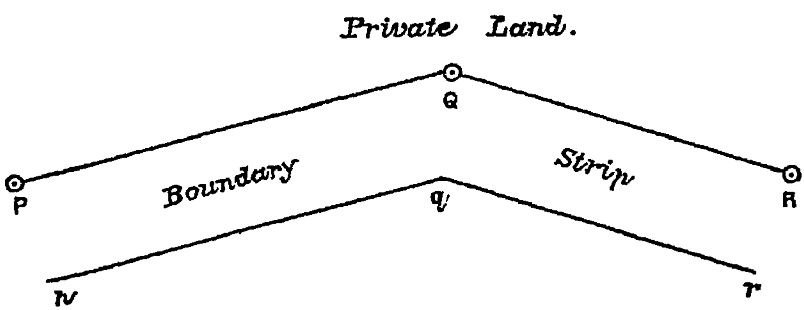


Figure 151 shows a boundary strip. The actual boundary of the forest is P Q R. *The space* Pp, Qq, Rr *is the boundary strip which is entirely cleared of vegetation of all kinds.* P, Q, R *are the marks put up when the survey of the boundary is first settled.*

and Pp, Qq, Rr the strip of reserved forest which has been cleared of vegetation of all kinds; the line P, Q, R will be the actual legal boundary line; and the strip P q R, the cleared boundary clearing or strip, will be entirely within the reserved forest.

The *boundary strips* or *clearings* should as a rule be freed completely from the growth of grass and weeds which springs up on them, and also of the branches of over-hanging trees; so that standing at any boundary mark a person may be able to see distinctly the adjacent boundary marks on either side. The *boundary strip* may be perfectly cleared of ground vegetation; but unless the trees on the strip are also cut, the over-hanging branches will often prevent one boundary mark from being clearly visible from the next one on either side. This is especially the case in the hill forests when one is looking down steep slopes.

In the Northern Circle of the Central Provinces, experience has shown that it is not necessary to remove the grass and weeds from the boundary clearings unless they are used as fire traces, in which case the clearing is effected by burning.

The boundary strips are usually cleared annually at the commencement of the working season. As a rule, in the rainy season in the plains of India, very little work goes on in the forest, so the vegetation is allowed to grow up on the boundary strips, and is removed at the commencement of the cold weather when work begins generally in the forests.

In the case of fire-protected forests, the boundary strips are cleared in connection with the protection of the forests from fire as soon as the grass, etc., is dry enough to burn freely after the end of the rains.

Where the ground is stony, the stones may be collected from the boundary strip and arranged along the actual boundary of the forest P, Q, R (fig. 151, page 304) so as to make a rough wall, which, even if only a few inches high, will be useful in showing the exact boundary of the forest.

§ 185. In some of the more remote forests, usually teak reserves, in the more distant parts of Burma, no boundary strips are cleared.

In these localities it is considered advisable to mark off and reserve the best teak-producing forests, which are found in areas clothed for the most part with less valuable species of trees, in order that they may be protected to supply the market with teak when the nearer forests have been worked out. These forests are as a rule situated in very thinly-populated districts where cattle or other trespass is practically unknown, so that it is only necessary to mark out the boundary in such a way that it can be easily and cheaply maintained and periodically inspected.

Here every boundary[1] has three kinds of marks—

1. Boundary posts.
2. Boundary boards.
3. Blazed trees.

1. The boundary posts are, in the hills, placed at salient angles and where the nature of the boundary changes, *e.g.* from a ridge to a stream, or from a main ridge to a minor ridge. In the plains they are placed so that one can be seen from the next. They are made of the heart-wood of some hard-wood tree; the most serviceable woods being Teak (*Tectona grandis*), Pyinkado (*Xylia dolabriformis*), Cutch (*Acacia Catechu*), Petwoon (*Berrya Amonilla*), Tseichyee (*Bridelia retusa*), and Gnoogyee (*Cassia Fistula*). The posts should be at least 2 feet 6 inches in girth and from $7\frac{1}{2}$ to 9 feet long; it is not necessary to square them as this only involves extra expense and does not add to their durability. Care must, however, be taken that all sap wood is cut off them. The posts should be buried from $1\frac{1}{2}$ to 3 feet in the ground, according to the nature of the soil in which they are erected, leaving 6 feet projecting out. Round the base of each post a conical mound of earth or stones must be made. Stones are preferable and the mound should have a diameter of at least 8 feet at the base, the height of the cone varying with the

[1] The late Mr. G. Q. Corbett, Deputy Conservator of Forests, Burma.

size of the stones available. If suitable stones are found locally, a rectangular dry masonry pillar 4 feet square and 4 feet high is suitable. In default of stone, earth must be used, and the cone of earth should reach to within 2 feet of the top of the post, while the diameter of the base varies with the nature of the earth. Another method which answers very well on clay soils is to make a circular framework of bamboo matwork all around the post 4 feet high at a distance of 4 feet from it, and to fill it with earth; when the bamboo rots the mound still retains its shape, but in sandy soils the earth soon finds its natural slope. Each post has a serial number on a zinc plate nailed on to it. The cost of a mound and post should never exceed R2.

2. Boundary boards are 18 inches long, 4 inches wide and 1 inch thick, and are made either of Teak (*Tectona grandis*), or of Pyinkado (*Xylia dolabriformis*); they are nailed to trees 200 yards apart in the hills and between each two posts in the plains, and in all cases where a path enters the reserve. The boards are painted white, and the vernacular for reserved forest is stencilled on them in black. These boards are not numbered, as in the event of any being missing it is easy enough to keep a stock of unnumbered ones and to replace the missing ones at once.

In affixing these boards to trees care must be taken not to drive the nail home, for if this were done the board would, as the tree grew, be forced off it. Large-headed nails should be used and at least 2 inches left protruding in front of the board. The boards should not be nailed to quick-growing trees; mature trees should be chosen if possible, as they grow very slowly.

3. Between the boards every tree along the boundary is blazed at a distance of 3 feet from the ground, the blaze is cut well into the heart-wood, on the side away from the reserve, and if there is no heart-wood deep into the soft-wood, and a hammer mark (the vernacular for "Reserved Forest") impressed on a smooth surface. These blazes should be re-opened about every third year. These trees are not numbered, and it is not

necessary that they should be, nor is it necessary that their girths, which vary from year to year, should be recorded in the boundary record.

The hammer marks last a great number of years when impressed on the heart-wood, and can be found after the blaze has completely healed up by cutting back to the old blaze.

§ 186. Boundary clearings or strips should be made, wherever practicable, into permanent inspection roads or paths, and where the country is flat enough, may, if required, be converted into export roads. In any case the export road or inspection road or path should follow the boundary line as closely as possible. In many cases it will be found that the ground will not allow of the exact boundary line being used; and in such cases the road should be taken round that portion of the boundary which is unsuitable for a road, by going into the forest, and returning to the boundary as soon as it becomes suitable. Thus, if a depression with abrupt sides, or a river with steep banks, is met, which would involve a very heavy cutting in order to obtain a road with a good gradient, the road should follow round the dip, if small, or else be taken at an easy gradient down one side and up the other instead of going straight down and straight up again following the exact boundary line.

It is much cheaper and better in every way to make the road deviate from the boundary lines as shown in figure 152 than to construct a wooden bridge in order to keep the road at a good gradient. Wooden bridges, besides being, in this case, unnecessary, are expensive to construct and must be kept in good order to allow of traffic passing over them.

In hill forests where the boundary strip is too steep to allow of its being converted into a path, it may be supplemented by a path which should zigzag up the hillside, coming out on to the boundary strip at intervals.

§ 187. BOUNDARY MARKS.—The typical method of demarcating the boundary of a reserved forest in India is to erect posts of wood, surrounded by a cairn of stones, or where these are

FIG. 152.

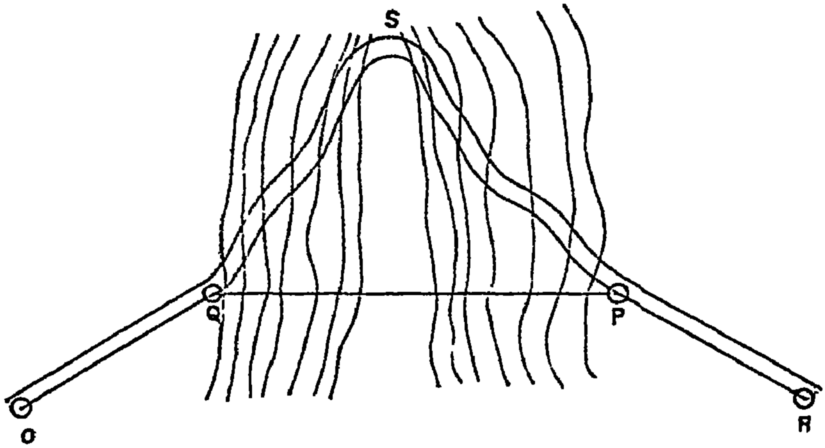


Figure 152 shows an instance when the boundary road should depart from the actual boundary line in order to avoid a steep fall and rise in the road itself. O, P, Q *and* R *are boundary marks, and the line* O, Q, P, R *the boundary line of the forest. The line between* P *and* Q *crosses a depression, as is shown by the contour lines. If the road were made to follow the exact boundary line, there would be a steep fall and rise in the line, which might make it unsuitable for traffic. In order to avoid this difficulty, the road is taken down one side of the depression at a suitable gradient and up the other side to meet the boundary line as soon as it is again suitable for a road.* P, S, Q *is the deviation of the road. The boundary strip from* P *to* Q *is of course cleared and kept up as the boundary of the forest.*

not available a mound of earth, and to clear a strip of forest between the successive boundary marks. The posts should be numbered serially, commencing, as a rule, from the north-west corner of the reserve and going along the north, east, south and west boundaries of the area.

The nature of the marks varies very much with the materials available locally for their construction, the character of the forest growth in the reserve, and the nature of the country bordering on it. In India the nature of the marks erected also depends upon the amount of money available for demarcation.

Whatever the nature of the boundary marks, it is very important that they should be erected in the proper places at the time that the boundary is laid out on the ground. The actual position of the boundary mark is of considerable importance; it should be placed so that the centre of the mark is over the point selected by the Settlement Officer.

One slight objection to placing the post over the point selected by the Settlement Officer and a cairn of stones round it, is that when you wish to take the bearing of the line at any subsequent date, in order to check the accuracy of the boundary or for any other purpose, you will not be able to place the prismatic compass or plane-table exactly over the post, but will have to set it up in an exact line between two adjacent pillars in order to obtain the bearing of the line; and the process of checking a long boundary will take considerably longer than if the survey instrument could have been put up exactly over the boundary mark. But the advantages of this procedure far outweigh the disadvantages and will prevent any possibility of disputes as to the correct or incorrect position of the boundary marks at some future date.

Where the boundary mark is regular in form, as, for example, a stone slab or a masonry pillar, then the pillar may be erected in any of the ways shown in figures 153, 154 and 155. In figure 153 the stone monolith or masonry pillar replaces the wooden post in marking the exact position of the point selected by the Settlement Officer. Figures 154 and 155 show other methods of erecting boundary marks where the land is valuable, as in the case of reserves near large towns; the survey pegs are replaced by small permanent stone bench-marks, and the boundary mark is placed close to the bench-mark.

The stone bench-mark may be of the shape shown in figure 156, and should have a broad arrow or some other distinguishing mark engraved on it. This arrow may be engraved so as to show the direction of one of the boundary lines meeting at the point marked by the bench-mark; or the direction of both the lines meeting at the point may be indicated by arrows cut on the top of the bench-mark.

FIG. 153.

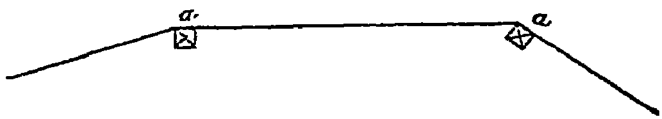


FIG. 154.

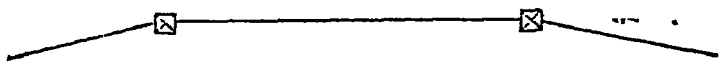


FIG. 155.

Figures 153 to 155 show different ways of erecting boundary marks consisting of rectangular masonry pillars or stones. In figure 153 the boundary marks are erected so that the centre of the boundary mark may be directly over the peg left when the boundary line was surveyed. Figure 153 shows another way of erecting such boundary marks. The masonry pillars are entirely within the reserved forest. The face of the pillar shows the direction of the boundary line, that of the first pillar is in the direction of the boundary line from the first to the second boundary mark, and so on. The left hand angular point a, a *of each pillar is on the peg left when the boundary line was surveyed. In figure 155 the peg is replaced by a stone bench-mark* b, *and the boundary pillar is erected just behind it. The boundary line runs from the centre of one bench-mark to the centre of the next.*

The actual legal boundary line will then run from the centre of the top of one stone bench-mark to the centre of the top of the next on either side of it.

All boundary marks should be numbered consecutively, starting from the point at which the boundary description in the final notification commences, and going in the same direction as the description so as to facilitate the checking of the boundary

FIG. 156.

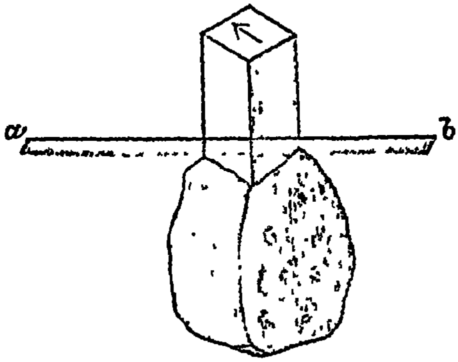


FIG. 157.

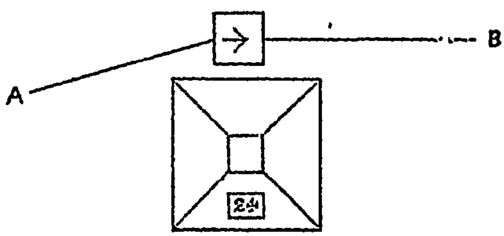


Figure 156 is a small stone bench-mark which may be put down to mark the exact position of the survey peg. The top part of the stone is cut square, the lower portion which is buried in the ground is not fashioned. The cut portion is 3 or 4 inches square. a b *is the ground level.*

Figure 157 shows the position of the bench-mark relatively to the boundary pillar. A B *is the boundary line of the forest. The arrow on the bench-mark may be used to show the direction of the boundary line as shown in the figure.*

itself, and also to render reports sent by range officers as to the locality of a fire, or a trespass, clearer. All the numbers of the boundary marks should be entered on the boundary maps which must be posted up to date. If the boundary marks are numbered, consecutively, any one can tell, by walking along the boundary, if any of the boundary marks are missing or not.

The boundary marks should be inspected regularly and must be kept in repair. The more permanent the marks set up the less repair will they require. If, as is the case in many parts of India, the boundary marks consist of wooden posts surrounded by a cairn of stones, or mounds of earth, some of the posts will require to be renewed annually, and the whole of them in the course of a few years. When the posts are renewed great care must be taken to see that the new posts are put up exactly on the site of the old ones. On no account should interpolations like 100 A be allowed.

Consecutive numbers may be used for the whole of a forest, or if the area be large, for the separate blocks of the forest, in the latter case the initial letter of the block should be added so as to distinguish the different series of figures one from the other. If the boundary marks are numbered by blocks, the number of pillars in each block will be comparatively small, and any subsequent alteration of the boundary will only affect the numbering of the boundary marks of the block in which the alteration of the boundary has been effected. The nature of the boundary marks used depends upon the nature of the materials available, and the other causes which have already been enumerated. Where stone is quarried in large slabs, as is the case in many parts of the Central Provinces, Oudh Madras and the Deccan, single large slabs of stone (monoliths), on which the number and other distinguishing marks are engraved, are the best and most permanent boundary marks that can be obtained. When stone and lime are both easily obtainable, masonry pillars with the consecutive number and other distinguishing mark engraved on a stone slab let into one of the sloping faces of the top of the pillar may be used. Where monoliths or lime cannot be cheaply obtained, wooden posts with consecutive numbers branded into or painted on them, surrounded by a cairn of stones, or mound of earth, if stones cannot be obtained, are commonly used.

Where flat stones are common, but lime not easily got, dry rubble pillars strengthened by wooden frames carrying a

small post bearing the number of the boundary pillar, may be used. Boards of a durable species of wood, with the number branded or painted on them, are largely used in Bombay and Burma as boundary marks. Branding the numbers is more durable than painting them. Where the undergrowth is very dense and high, the boards should be fixed on to the trees by a man standing on a ladder or the back of an elephant, so as to allow of their being seen when the undergrowth is not cut. The boards should be fastened to the tree with two large nails.

In the Southern Division of Kanara (Bombay Presidency), boards are being replaced by galvanized iron plates 10 inches square backed with wooden battens six inches long, ¾ inch wide and ½ an inch thick to keep the plates from contact with the bark. These plates are fastened to trees by one or two nails driven through the plates and batten into the tree. Large nails should be used, and they should not be driven home, but their heads should project at least an inch from the board, so that the tree in growing may not force the board off the tree. Ordinary iron plates, with the numbers cast or engraved on them, may be used instead of boards or galvanized iron plates. In Kanara, plates placed with one side horizontal and painted white indicate reserved forests, while plates placed with one angle at the top and painted red are used to demarcate protected ones.

The use of boards nailed on to trees as boundary marks has much to recommend it when large areas have to be taken up in parts of the country which are but a little opened up. They are cheap, easily obtained and placed in position, and if placed high up on the trees, can be seen from a distance, even if the undergrowth along the boundary line is not cleared. As the country becomes more opened up, they can be replaced by more permanent marks.

Iron plates fixed to iron posts may be substituted for wooden posts in localities where bad forest fires are of frequent occurrence. Where the boundary of a forest has been cut away by a stream, so that the existing boundary lies in the bed of a

stream which only contains water in the rainy season, this portion of the boundary line of the forest may be laid out annually as soon as the stream has assumed its cold-weather level, especially in cases where the river bed contains limestone from which revenue can be derived.

Trees with rings of paint round them, marked and numbered, may be used as boundary marks. In this case the mark and numbers should be cut well into the heartwood so as to prevent their being grown over and included in the stems of the trees. Where living trees are used as boundary marks, the species, if accurately known, and the girth of the tree should be noted in the boundary record.

When the boundary line is an artificial line, the boundary marks must be visible one from the other, and the actual boundary line of the forest will run straight from one mark to the next on either side of it. The fewer the boundary marks put up, the cheaper will be the demarcation. In the case of natural boundaries, such as a well-defined stream, ridge, road or high bank, it is only necessary to erect boundary marks where the boundary begins to follow the ridge, etc., where it leaves it and at such points along the natural boundary where there is the slightest possibility of the boundary being mistaken. Where the natural boundary is a long one, the pillars put up should not be more than ¼ mile apart.

§ 188. COMMON FORMS OF BOUNDARY MARKS.—The most generally used form of boundary mark in India is a wooden post surrounded either by a heap of stones, or in the absence of stone, a mound of earth. The posts should be cut from the most durable species of tree that is found in the forest which is being demarcated.

In the South Arcot Division, Madras Presidency, the posts are barked and well tarred, the part which is buried in the ground being first charred. The posts are 8 feet high, 4 to 6 inches in diameter and are buried 2 feet in the ground.

In the Ruby Mines Division, Upper Burma, sawn teak posts from 6 to 7½ feet high and 6 inches square, or else round

teak posts, are used. The posts are buried from 1½ to 3 feet in the ground.

In the Northern Circle, Madras Presidency, the wooden posts used are 6 feet high and not less than 6 inches in diameter.

In Burma, the wooden posts are made of the heartwood of the most durable species of wood available and vary in length from 7½ to 9 feet, of which from 1½ to 2 feet are buried in the ground. The girth of the post should not be less than 2½ feet.

Where white-ants are abundant, only those kinds of trees which are but little attacked by white-ants should be used, and the post should be embedded in and surrounded by sand to a depth of at least 1 foot.

In other parts of India the posts are usually cut from saplings of inferior species growing in the forest near the boundary line. This procedure reduces the cost of the erection of the wooden pillars in the first instance, but as such posts only last from two to six years according to the locality in which they are placed, the cost of upkeep of the boundary is increased, as a considerable number of posts have to be renewed annually.

The size of the cairns or heaps of stones also varies considerably in various parts of India and Burma.

In Burma, the late Mr. Corbett says they should be at least 8 feet in diameter at the base, the height varying with the size of the stone used.

In the Northern Circle, Madras Presidency, stone cairns are circular in plan, 4 feet in diameter at the base and 2 feet at the top, the height being 4 feet.

In the Berars, the cairns are circular in plan, 5 feet in diameter at the base and 4½ feet high.

When the cairns are first erected, a foundation bed from 6 inches to 1 foot deep should be prepared and the cairn built in this, so as to make it more permanent.

Mounds of earth are placed round the posts when no stones are available near at hand. The earth mounds are made the same size as the stone cairns. In clay soils, a framework of split bamboo 4 feet high and 4 feet in diameter may be erected

round the post and filled with well-rammed clay; when the bamboo rots the mound will still retain its shape, but where the soil contains much sand it will soon assume its natural slope. Earthen mounds should be turfed.

Marks are placed on the wooden posts to show that they mark the boundary of the forests. The marks should face outwards, so that they may be seen by any one coming into the forest from the outside. The serial number on the post may be placed looking inwards where a strip is cleared on the inside, so as to allow of its being seen by the inspecting officer when he is examining the boundaries of the reserves.

The marks are either cut into the posts or painted on them. They usually consist of the letters R. F., standing for Reserved Forest, and a serial number. Where there are more than one series of numbers in a division, the distinguishing letter of the serial number should also be added.

Where the number of the boundary pillars in a reserve is large, there may be a separate series for each block, or other convenient division of the forest, so as to obviate the necessity of using large numbers. It is very necessary that the posts should be serially numbered, as, if this is done, a glance at the numbers will show if any pillars are missing. No interpolated numbers should be allowed, such as 120A, 120B, when the area is first demarcated. If the boundary is subsequently altered and some pillars are omitted or added, it is better to alter the numbers of the pillars on the boundary than to interpolate posts with letters on them, if this can be done at a reasonable cost. Of course all changes in the boundary must be written up at the time the change is made in the boundary record of the Block.

The cost of erection of a wooden post surrounded by a cairn of stone or mound of earth varies in different parts of the country with the cost of labour and the distance the materials have to be carried from six annas to two rupees.

In the Northern Circle, Bombay Presidency, and in some parts of the Central Provinces, stone cairns are used as

boundary marks with a large stone inserted at the top of the cairn on which the serial number and other distinguishing marks are painted or engraved.

The cairns are made of different sizes, and are circular in plan. The large cairns have a diameter of 7 feet at the base and 5 feet at the top with a height of 3½ feet, while the smaller ones are 3½ feet in diameter at the base, 2½ feet at the top and are 3 feet high. In either case the height does not include the height of the inscribed stone placed in the cairn. This is usually 15 inches high and square in plan. It is painted white for forests open to grazing, and red in the case of forests closed to grazing. The foundation bed in which the cairn is built is 6 inches deep.

The cost of these boundary marks varies with the size from four annas to one rupee.

In the Northern Circle, Madras Presidency, stones of suitable dimensions are also used to replace wooden posts when the latter decay.

Dry rubble masonry boundary pillars are used in the Jaunsar Division and in the Ranikhet Sub-division, North-Western Provinces, where suitable stone is available.

In Jaunsar the pillars are cubical in form, the side of the square being 4 or 2 feet, according to the position and importance of the pillar. The serial number is cut or painted on a small scantling fixed to a wooden frame embedded in the pillar.

In the Ranikhet Sub-division, the pillars are circular in plan. The foundation is 1 foot deep and 4 feet in diameter, the pillar proper being 3 feet 6 inches in diameter at the base, 2 feet at the top and 3½ feet high above the ground. A wooden slab bearing the serial number of the pillar is embedded in it.

Masonry pillars (stone set in lime mortar) are used in the Dehra Dun, Saharanpur and Naini Tal Divisions, North-Western Provinces.

In the Naini Tal Division the masonry pillars used to demarcate pieces of cultivation included in the reserved forest

are 2½ feet high, of which 1 foot is foundation and 1½ feet project above the surface of the ground. The pillars are 1 foot square. The top of the pillar is a truncated pyramid, the top being 3 inches square and the height also 3 inches. The serial number of the boundary mark is engraved on a slab of slate 3 inches square let into the side of the pillar.

The pillars which are placed on the external boundary of the forests are similar in shape, but are 1½ feet square and 3½ feet high, of which 1½ feet are in foundation and 2 feet project above the ground. The serial number is engraved on a slab of slate 6 inches by 4 inches embedded in the side of the pillar.

In some parts of the Madras Presidency and in Oudh, monoliths are used as boundary marks, the serial numbers and other distinguishing marks being engraved on them.

In the South Arcot District, Madras Presidency, monoliths of two sizes are used, the large ones being placed at the more important points on the boundary. The large stones are from 6 to 8 feet high, 1 foot wide, and from 4 to 6 inches thick; the smaller ones being 4 or 5 feet high and the same width and thickness. The upper 2 or 3 feet of the stone posts are painted white, and the serial numbers and marks are engraved or painted in black on them. The following marks are placed on the monoliths :—

(1) R. F., standing for Reserved Forest.
(2) ↑
(3) The number of the block.
(4) The serial number of the boundary mark.

Each block of forest has a separate series of numbers.

In Oudh, the monoliths are 5 feet high, 9 inches wide and 6 inches thick. Only the upper half is squared, the lower half, which is embedded in the ground, being only roughly shaped. They weigh about 5 maunds and cost R3-12, delivered at any railway station.

In South Kanara, Bombay Presidency, monoliths of granite, basalt or sandstone, according to the locality, 3 feet high,

10 inches wide and 5 inches thick, are used and cost 13 annas each, delivered where they have to be erected. The letters R. F. and the serial number are printed on them.

In the Darjeeling Division, Bengal, the wooden posts in cairns of stones are being replaced by concrete boundary pillars.[1] These boundary pillars are in the shape of a hollow, bevelled, truncated cone, and have a hollow in the base to allow of their being carried by one man.

The diameter of the base is 18 inches, the diameter of the hollow is 10 inches and its height 13 inches. The total height of the pillar is 18 inches.

The circumference of the base is 4 feet 8 inches at the top, below the level 3 feet 3 inches. The thickness of the concrete is 4 inches. The weight of each pillar is about 1½ maunds.

The pillars are made in wooden moulds, which consist of four parts, the top, the two sides and the block which forms the hollow. This block is made up of separate pieces of wood which can be removed separately if the block will not come out as a whole. This block is kept in position by being screwed on to a cross-piece which is also screwed into the sides of the mould. The sides are joined by clamps of wood which are screwed on to them.

The top piece has a rectangular opening, in which a plate containing the numbers and marks which are to be cast in the concrete pillar is placed. Each pillar is marked F ↑ D, and a serial number in the vernacular is added. A later type of mould has the marks on the side instead of the top of the pillar.

The quantities of materials required for one pillar are approximately as follows:—

Materials.	Mds.	srs.
Broken stone	1	2
Portland cement . . .	0	17
Sand	0	9
Oil or grease	0	1⅜

Designed and made by Mr. F. B. Manson, Conservator of Forests, Burma.

The cost of a pillar, calculated on the 334 pillars that have been made, is about R3 at the place where the pillars are moulded, which is accounted for as follows :—

	R	*a.*	*p.*
Average cost of materials and labour	2	11	0
" " of moulds, dies, sheds, etc.	0	5	0
	3	0	0

The Portland cement is the most expensive item : the railway freight on the Darjeeling-Himalayan Railway being very heavy. In places where clear gravel and river sand are procurable and the cost of Portland cement is comparatively small, the cost per pillar would be much less.

In the Madras Presidency signboards are fixed to trees to indicate rights-of-way and also where every path or road enters into or borders on a reserved forest, and also to mark forest topes, forest depôts, forest offices, forest stations and forest camping grounds. These signboards consist of zinc or tin plates 15 inches high and 12 inches broad. They are painted white on both sides, and letters one inch high are cut out of the plates. The plates are nailed to one inch boards (½ inch boards set crosswise). The boards to which the plates are fastened are tarred on both sides. The plates are so fastened that by temporarily slipping a piece of tin or zinc behind the plate, the plate can be repainted white without touching the black board to which it is fastened.

These signboards are fastened by one nail so as to hang perpendicularly from suitable posts or trees. They cost about 12 annas each.

When placed on a road or path that enters a reserved forest they should be placed on the left-hand side of the path or road, as you enter the forest. Where a road or path borders on a forest, a signboard should be placed where it first touches and where it last touches the reserve. In the Madras Presidency every path that touches a boundary and every right-

of-way is marked with such a signboard. The particulars of the right-of-way are stated on the board. Where a path borders a reserve, the board should be parallel to the path. In the case of paths that enter a reserve, the board should face at right angles to the path, and in all cases it will face away from the area that it defines.

§ 189. Under certain circumstances it may be necessary to mark the boundary of a forest still more definitely than by boundary marks and a cleared strip. This may be done by digging a small furrow in the ground (*dák bel*), connecting each boundary pillar with the two pillars on either side of it. Such a furrow will remain visible for a number of years under ordinary circumstances and can be renewed at a small cost.

In the plains of the Punjab, the boundary between the pillars is marked by a series of interrupted ditches. A ditch 10 feet long is dug, the next 100 feet of the boundary is left untouched, and then another ditch 100 feet long is made, and so on.

In the Northern Circle of the Bombay Presidency, *pointers* are placed along the boundary to indicate its direction between the pillars.

The pointers consist of small stones embedded in the ground placed on the boundary of the forest. Two pointers are usually placed on each side of each cairn of stones. The first pointer is placed 6 feet from the pillar and the second one the same distance from the first one. They are painted the same colour as the large stone placed in the stone cairn.

§ 190. In a flat country, where there is little or no grazing and where the rainfall is light, the boundary line may be marked by a ditch running from one boundary mark to the other. If a ditch is made, the full width of the ride should be cleared, exclusive of that of the ditch. The soil which is removed from the ditch may be used to make a boundary road, or else placed so as to form a mound. The ditch or the mound may be on the outside, so far as the forest is concerned, as is shown in figure 15[8], page 323; but both must be within the forest boundary.

FIG. 158.

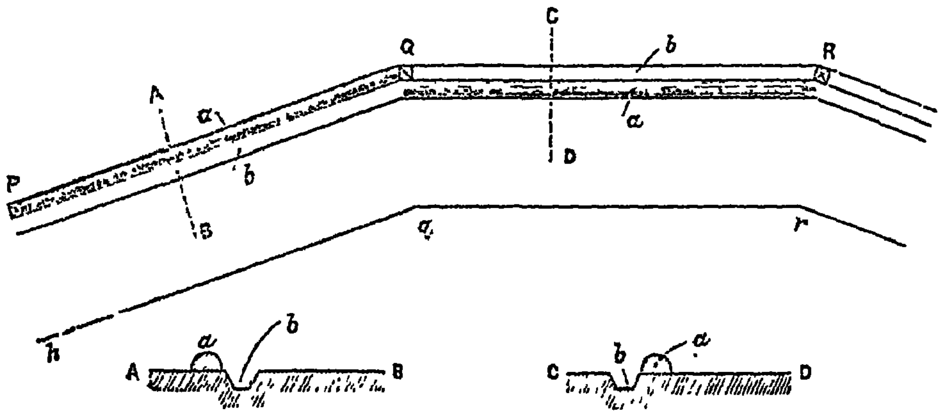


Figure 158 shows two methods of marking the boundary line of a forest by a mound and a ditch. The mound may be outside, as shown between the two boundary pillars P *and* Q, *or inside, as between* Q *and* R. *Sections through the boundary ditch and mound along* A B *and* C D *are shown below.* P, Q, R *are boundary pillars.* a, a *the mounds and* b, b *the ditches which mark the boundary line.*

P, q, R *is the boundary strip. The pillars are entirely on forest land.*

In one case the outer edge of the ditch will be along the actual boundary, in the other case the outer edge of the base of the mound will mark the exact boundary of the forest.

In Bahraich, Oudh Circle, where grazing is very heavy, there is hardly any trace (1897) of a ditch 2 feet wide and 2 feet deep dug in 1885 (*Mr. F. A. Leete*). Mr. Leete thinks that this is chiefly due to the earth having been placed in a mound alongside the ditch and not planted, and having been trodden into the ditch by the cattle, and he advocates the earth being thrown about 10 or 15 feet away and spread out evenly.

Where the rainfall is heavy, the boundary line should never be marked by ditches in hill forests, when it is taken up and down steep slopes; as ditches in such situations are liable to turn into drainage channels, and may eventually develop into ravines.

Where there is a ditch and a mound, the mound may be planted so as to form a hedge, which will be of use in keeping out cattle, as well as in marking the exact boundary of the forests. The following species may be used to make hedges :—

Northern India.—Aloe (*Agave americana* and other species) makes an excellent hedge, perhaps the best. The plant is furnished with spines, and the leaves are fleshy and strong. When the hedge is complete, it forms a very good protection against cattle, but is rather liable to be damaged by porcupines. The aloe does well in Southern India and even on the West Coast, but has proved a complete failure in the Northern Circle of the Central Provinces (*Mr. E. E. Fernandez*).

In many parts of the North-Western Provinces and Oudh rows of simul (*Bombax malabaricum*) and jhinghan (*Odina Wodier*) cuttings are planted along the boundary lines, in a mound of earth. These when grown up into large trees make the boundary at once conspicuous, and the cost of the construction and repair of a large number of intermediate boundary pillars in long lines is avoided.

Roses (*Rosa sp. sp.*) are used extensively for hedges in the Dehra Dun Districts and grow well in the Lower Himalaya, both in the North-Western Provinces and in Bengal.

Jatropha Curcas and *Vitex Negundo* are also used for hedges of fields in the plains portion of the Saharanpur District of the North-Western Provinces. They are both too soft to form an efficient protection against cattle; the latter is very common on the East and West Coasts of the Madras Presidency. *Crataegus Pyracantha* is similarly used in the Kumaon Hills.

South India.—Prickly-pear (*Opuntia sp. sp.*) makes a good hedge, but spreads away from the mound and should in consequence be avoided. Karkapilly (*Inga dulcis*) is one of the best shrubs for hedges; if properly trimmed and cut back it grows very thick and becomes absolutely impenetrable.[1] Screwpine (*Pandanus fascicularis*) is also used for hedgerows near the sea-coast in Madras.

[1] Mr. W. G. Beetham, Officiating Conservator of Forests, Bombay Presidency.

In the Coimbatore and Salem Districts of the Madras Presidency *Balsamodendron Berryi* is universally used for hedges. Sanatha (*Dodonæa viscosa*) and mehndi (*Lawsonia alba*) are also used in Madras for quickset hedges.

When the climate is suitable, shisham (*Dalbergia Sissoo*) can be made into a good hedge. In the Ajmer District thor (*Euphorbia Nivulia*) is very largely used for making boundary hedges, and if properly attended to is sufficient to keep cattle out of the forest. The thorny bamboo (*Bambusa arundinacea*) makes a good and almost impenetrable hedge, but takes up much room. In some parts of South India the Palmyra palm (*Borassus flabelliformis*) planted close is used to demarcate fields and is also excellent for forest boundaries.

Quickset hedges, besides defining the actual boundary line are very good for protecting the forest from fire and also grazing. If they are to be serviceable, any gaps which occur in them should be immediately filled up.

Quickset or living hedges are much better than dry hedges made out of branches of thorny trees. The species most generally used for making dry hedges are the different species of *Zizyphus*, *Carissa*, thorny *Acacias*, *Cæsalpinias*, and bamboos.

It is impracticable and unnecessary to form quickset hedges round every reserved forest. The formation of quickset hedges should be confined to the fencing of areas under natural regeneration, nurseries, or plantations where it is necessary to keep cattle from destroying the young seedlings which have come up naturally, or have been brought artificially on to the area.

Dry-rubble stone walls form a very good boundary, but are expensive to make. However, in thickly-populated districts, if it is intended that the protection of the forests from grazing is to be effectual, a wall, fence, or hedge must be constructed to keep out the cattle.

Dry-rubble stone walls were constructed round some of the reserved forests in the Anantapur District in the Madras

Presidency about 3 feet high, 2½ feet wide at the base, and somewhat narrower at the top for R100 a mile, and were most effectual as a protection against grazing.

Similar walls, 3 feet high, have been constructed round the Baldhoti and Kalimat *chir* pine plantations near Almora.

Posts and rails, wire fencing, or wire with stone or wooden posts may be used where it is essential that the area should be effectually protected from trespass; barbed wire is most effective in keeping cattle out of a plantation. A combination of a wooden fence and a live hedge is also good.

§ 191. SURVEY OF THE BOUNDARY LINE AND ERECTION OF BOUNDARY MARKS.—In the example given in § 182, page 301, the boundary of the forest which has to be surveyed is that bounded by the figure *a b c d e f* B C D E *a*. This line should be surveyed as soon as the permanent boundary pillars have been erected on the points approved by the Settlement Officer. The survey of the boundary should, if possible, keep up with the Settlement Officer's movements as mentioned in § 182, page 301, but in any case permanent boundary pillars must be erected before the time the survey is made. Wooden posts placed in mounds of stone or wood are generally used for this purpose, or where the demarcation is a rough one (as, for instance, in Upper Burma) posts are erected at fixed intervals and trees between the posts along the boundary line are blazed and marked with a special hammer. If it is not practicable to survey the boundary at the time that the Settlement Officer lays it down, boundary pillars should always be erected marking out the line, and the survey of this line can be made as soon as officers can be made available for this duty. The survey of the boundary should be made as soon as possible after it has been fixed to prevent any possibility of its being altered.

It is very important that a gazetted officer should inspect the permanent boundary pillars as soon as the demarcation of the boundary has been completed. When inspecting a new boundary the gazetted officer should take the boundary record

with him and carefully compare the entries in the boundary record with the boundary line and marks on the ground. The boundary record should be corrected, wherever this is found necessary, so that it may be an accurate description of the existing boundary line of the reserve.

The survey and numbering of the boundary marks should, for the sake of uniformity and to prevent subsequent confusion, always commence at the north-west angle of the reserve and proceed regularly along the north, east, south and west boundaries (*Mr. F. A. Lodge*).

The field book of the survey should give—

(1) The prismatic bearing of each line, *i.e.* the bearing of each line referred to the magnetic north. The variation of the needle, *i.e.* the angle between the true north and magnetic north, at the time and place the survey is made should also be recorded.

(2) An accurate description of each boundary mark erected, together with such letters or other distinguishing marks as may have been put on it.

(3) The distance between the individual boundary pillars measured along the surface of the ground, as well as the reduced horizontal equivalent where the boundary is on sloping ground.

(4) The points at which streams, roads, foot-paths, etc., cross the boundary line, together with such information with regard to their width, etc., as may be possible.

(5) The points where the boundaries of external properties meet the forest boundary, as well as the names of such properties.

(6) Bearings to easily recognisable houses in villages close to the boundary and to such notable physical land-marks as may be visible from it.

(7) The names of the village lands adjoining the selected boundary.

The stations at which the prismatic compass or other surveying instrument used is placed must be carefully and accurately marked.

The kind of chain used, whether it is a Gunter's or a 100-foot one, should be noted, and the accuracy of the length of the chain must be tested before the work is begun. The length of the chain should be checked with a new and accurate measuring tape, which should be used for this purpose only, before and after each day's work, in order to ensure that the distances recorded in the field-book are the actual distances measured on the ground.

The magnetic variation, *i.e.* declination or divergence from the true north of the prismatic compass or needle used with the plane-table, must be found out and recorded; since the variation of the needle differs from place to place, and also slightly from year to year; and unless the variation of the needle or true north is known or recorded on an old map, it will not be possible to compare accurately future surveys with those made previously.

The accuracy of the prismatic compass should be tested before the work is begun, and from time to time as it proceeds. The number and other distinguishing marks of the prismatic compass or other instrument used should also be recorded for future reference.

§ 192. BOUNDARY RECORD AND BOUNDARY MAPS.—The correct compilation of the boundary record and the preparation of boundary maps is of the greatest importance, and is just as necessary as the proper laying out of the line on the ground, for in case of disputes, the boundary line, as it exists, can be re-surveyed and compared with the record of the line as it was originally laid out. If the surveys coincide, no further proof is necessary that the existing line is the same as that which was originally laid down. The boundary record may be the actual drawn up from the field-book of the boundary survey in a more compact form.

The following information should be given at the commencement of the record of the boundary of each reserve, together with the date of the actual survey, and a brief account of how and by whom the survey was effected, and any difficulties which were met with during the actual surveying operations:—

(1) the number and other distinguishing marks of the prismatic compass or plane-table and needle-compass used;

(2) the magnetic variation of the needle, or divergence from the true north according to the line or place of making the survey;

(3) the kind of chain used, whether it was a Gunter's, a 100-foot, or a 50-foot one;

(4) whether the measurements entered on the record are in links or feet, and how the measurements along the surface of the ground recorded are distinguished from their horizontal equivalents; and how the latter were obtained from the former.

Both the surface measurements and their horizontal equivalents should be given. The surface measurements are required when checking the distances between the boundary marks on the ground; and their horizontal equivalents are necessary when a map is being prepared from the boundary record to compare the boundary with that shown on other maps.

(5) The chain error before and after each day's work should be noted and applied to the individual lines before their lengths are entered in the boundary record, or plotted.

(6) Any accidents which may have occurred to any of the instruments used, and the manner in which they were remedied.

The boundary record may be kept in the form shown below, which is a somewhat modified form of that used in the Kurseong Division of Bengal.

Boundary Record of .... Reserved Forest, ... Division .... Province.

Nature of boundary mark.	Number or distinguishing mark on it.	Forward bearing to the next boundary mark.	Distance in feet (or links).		Remarks.
			Surface-measurement.	Horizontal equivalent.	
Wooden post in cairn of stones.	1	$243\frac{1}{3}°$	472	450	On the east edge of Sukna Sivoke cart-road, where it crosses the Darjeeling-Himalayan Railway. Line fairly level, at 240 (surface-measurement) crosses small stream. Bearing to Sukna Station well 162°.
Ditto	2	195°	643	643	Level. At 400 (surface-measurement) bearing to Mohurgong Factory 143°.

In the remarks column the distances from the last station to the points at which streams, roads, foot-paths cross the line should be noted, as well as the nature of the ground passed over. Bearings should be taken from convenient points on to conspicuous natural objects, such as well-known hills, or on to conspicuous houses in villages, with a view to fixing the exact position of a pillar if it is lost or destroyed. The points at which external properties meet the forest boundary should be noted. The position of the first boundary mark must be very carefully described, and its distance from some permanent and easily recognisable place noted.

Besides the boundary record, boundary maps should be prepared from the survey of the boundary, showing all the information that can be collected about the boundary line and external properties bordering on it. The bearing of each line should be entered on the map on one side of the line itself, except in the case of a plane-table survey, where no bearings are taken, and the distances measured along the surface of the

ground and their reduced equivalents on the other, so that the boundary map may show all the information contained in the record of the boundaries.

Copies of all the boundary maps should be kept in the Conservator's office; and those of the forests of each Division or each Range in the Divisional or Range office, respectively, as the case may be. Any changes in the boundary itself, or in the nature of the boundary marks, or the numbers and other distinguishing marks on them, should be at once noted in the boundary records, and the necessary corrections made in the boundary maps, so that the boundary record and boundary maps may always represent the existing state of the boundaries.

The importance of having the record of the forest boundaries and forest boundary maps kept correctly up to date in a systematic manner cannot be over-estimated, nor can it be too strongly insisted on that there must be two copies in different places, so that in case of fire or other accident the record may not be completely lost. In many cases it will be well worth while to have the boundary records printed.

The boundaries of village lands enclosed within the outer boundary of the forests are in some parts of India—for example the hill forests of the North-Western Provinces of India—of just as much importance as the outer boundary. They should in this case be demarcated by pillars of a different shape and size (usually smaller) from those used to define the outer boundary of the forest, and should be numbered serially and separately for each piece of enclosed land.

APPENDIX I.

SLEDGE ROADS IN INDIA.

Extracts from a Report on the Deota Sledge Road, by E. McArthur Moir, Deputy Conservator of Forests (1885).

The construction of the Deota sledge road was commenced in June 1883 and was completed in July 1884, the sledge road being opened to traffic on the 1st August 1884. The prepared track on which the sledge road was laid was 6 feet wide. The length of the road was 5,877 feet, including twenty bridges, aggregating all together 1,068 feet. Fourteen thousand cubic feet of hard rock were blasted in order to make the 6 feet track, 400 lbs. of blasting powder being used; 7,500 cubic feet of retaining walls were built. One or two large cuttings were also found necessary. The longest bridge on the sledge road was 107 feet in length. It consisted of three spans of 33, 48, 17½ feet, respectively; the two main piers which were respectively 28½ and 27½ feet high, were built of dry-rubble masonry tied together with beams of Deodar (*Cedrus Deodara*) or kail (*Pinus excelsa*) well notched on to each other. The stone-work was surmounted by timber cribworks, on which beams supporting the roadway were laid.

The sledge road proper was made entirely out of rejected deodar sleepers which were lying in the forest, and the principle of construction is similar to that shown in figures 29, 30 and 31 (pages 50 and 51). The cross pieces were, however, uniformly 30 inches apart; those fastened to the beams of the bridges were fixed by 6-inch nails instead of wooden trenails. The portion of the roadway between the longitudinal beams was filled in with the best available ballast, up to a level with the bottom of the transverse sleepers, so as to make the roadway more solid, and to form a path for the sledge-men to walk on. Guards, made of half metre-gauge sleepers, were fixed on the outside of sharp curves to prevent the sledges running off the road at these points.

Owing to the steep nature of the hillsides, a careful system of drainage was considered necessary. A deep drain was made along the inner side of the roadway, and the rain water which was caught by it led under the sledge road in wooden troughs placed in suitable positions. The sledges used were similar to that figured on pages 55 and 56, figures 35, 36, and 37.

The gradient of the roadway varies from 5 to 11 degrees, the average being 8 degrees. The best gradient is between 7 and 8 degrees.

The sharpest curves on the road have a radii of from 20 to 22 yards. The sledges are worked down by two men as described on page 57, § 37,

the empty sledges being carried up by the same men who worked them down.

The bridges and most dangerous places were provided with railings for the protection of the sledge-men. In very wet weather considerable difficulty was experienced in starting the sledges and also in controlling them during transit; and in consequence sledging was not allowed when the weather was very wet. In favourable weather experienced sledge-men used to make five or six trips in a day.

At first, sledging through a contractor was tried at 4 pies per sleeper, but a system of passes was soon introduced which has been found to work well, a pass being given for each loaded sledge which reaches the lower depôt. The rate paid per sleeper was 3 pies. The rate paid for carriage on coolies' backs over the same section before the sledge road was made was one anna. The following statement, showing the actual saving on the sledge road, has been prepared by Mr. McArthur Moir :—

EXPENDITURE.	R	a.	p.	R	a.	p.
Capital—						
Original cost of sledge road	3,587	0	0	3,587	0	0
Interest on capital expenditure at 4 per cent. compound interest for five years				778	2	0
Working Expenses—						
Repairs, 1884—90	1,767	7	3			
Cost of sledging 307,174 metre-gauge sleepers up to 1890	4,055	13	3			
Cost of iron, ropes, ghee,[1] oil, and soap, etc.	620	0	0			
Cost of construction and repair of sledges	715	0	0	7,158	4	6
GRAND TOTAL				11,523	6	6

If the sledge road had not been made, the expenditure would have been as follows :—

	R	a.	p.
Carriage of 307,174 metre-gauge sleepers at 1 anna each	19,198	6	0
Construction of cooly-carrying path	116	0	0
Repairs to the same	90	0	0
Commission to contractors on R19,198-6 at 5 per cent. (the rate paid at that time)	959	14	9
Loss on the food-supply	601	3	0
TOTAL	20,965	7	9

Food is carried out to Deota and supplied to workmen engaged on forest works at a slight loss to the Department. Food, sufficient for the wants of the men employed on forest works, cannot be obtained locally, and it has been found necessary to supply food departmentally in order to ensure a proper supply of workmen. This loss was estimated as follows :—

The cost of the work of extracting the sleepers by manual labour would have been R20,364-4-9; the cost of construction and working of the sledge road was (neglecting interest on capital) R10,745-4-6. The difference

[1] Clarified butter.

between these sums is R9,619-0-3. Supposing three men would earn R1, this sum would represent the wages of 28,857 extra coolies, and as the loss on the food supplied is estimated at 4 pies per man, this would represent the sum of R601-3 shown above.

Consequently, the net profit to Government is the difference between R20,965-7-9 and R11,523-6-6, that is R9,442-1-3. Had the gain in transport, owing to the use of the sledge road, been applied year by year to reduce the capital outlay, the net profit would have been slightly greater.

Extracts from a Report on the Thadiâr Sledge Road, by E. McArthur Moir, Deputy Conservator of Forests (1890).

The Thadiâr timber slide was completely wrecked, with the exception of about 10 chains in the rice-fields near Thadiâr, on the night of the 8th August 1889, by an unprecedented flood, which not only carried away the slide, but entirely altered the physical features of the bed of the stream. Some means of transport had to be devised at once in order to deliver the 85,000 sleepers which were required to complete the 100,000 sleepers, for which a contract had been taken, and a sledge road was finally decided upon. This sledge road is similar in construction to the one made at Deota. The alignment of the road was begun on the 20th August, and the construction on the 27th of the same month, and the sledge road was open for sledging on the 12th December.

The general direction is fairly straight, and the curves much fewer in number than on the Deota sledge road. The length is 7,960 feet, including 1,804 feet of bridges and viaducts.

The width of the prepared track was 6 feet. The quantity of rock blasted was about 5,000 cubic feet, and 110 lb. of powder and 100 Holt's blasting cartridges were used; the results obtained from the latter were most satisfactory.

The cubic contents of the retaining walls, which it was necessary to construct, were 15,800 cubic feet. These walls were made of dry rubble and strengthened by the addition of wooden beams notched on to each other, which effectually prevented the walls from being shaken down by the jolting of the sledges.

There are twenty-one bridges, the longest traverses rice-fields and is 368 feet long, made up of 14 spans. The bridge, which has the greatest individual span and crosses a dry nullah which is 57 feet deep, is itself 68 feet long, the principal longitudinal beam being supported by a straining beam, struts, and braces (see figure 77, page 161, Part IV, Volume II). The total amount of dry rubble masonry in the piers of the bridges amounted to 20,000 cubic feet.

Chir (*Pinus longifolia*) beams were used in the construction of all the bridges, as it was the nearest at hand, it being estimated that if tarred, these beams would last four or five years. This estimate proved correct, as it has not been necessary to renew any of the beams since the bridges were first erected. One thousand one hundred and fifty-one feet of substantial wooden

railings were constructed on bridges and along the most precipitous places on the line.

The longitudinal beams of the sledge road were made of Chir (*Pinus longifolia*), and were 12 feet long by 5 inches square. The cross pieces consisted of deodar (*Cedrus Deodara*) metre-gauge sleepers sawn down the middle.

The system of drainage of the road employed is similar to that which was used at Deota.

The gradient of the sledge road varies from 4 to 10 degrees, the average being between from 5½ to 6 degrees, more than half the road having a gradient of between 4 and 5 degrees. The highest gradient on the bridges is 10, the lowest 4 degrees. Where the gradient is less than 6 degrees, the cross pieces are placed 2 feet apart; where it is more than 6 degrees, the distance between the cross pieces is 2½ feet.

This sledge road was in working order up to December 1893, so was in use four years. When inspected in May 1894, the lower portion of the sledge road was absolutely unfit for traffic, the roadway of the bridges were unserviceable, and in some places the *chir* longitudinal scantlings were decaying, but the beams of the bridges were still sound. This shows that the wood of *Pinus longifolia*, placed in the ground in a damp hot valley at an elevation of 4,000 feet, will only last about four or five years.

The following statement drawn up by Mr. Moir shows the saving effected by the Thadiâr sledge road :—

EXPENDITURE.	*R a. p.*	*R a. p.*
Capital—		
Construction of sledge road in 1889 .	4,534 0 0	
		4,534 0 0
Compound interest on capital at 4 per cent. for four years	...	770 2 3
Working Expenses—		
Cost of repairs, April 1890 to December 1893	1,231 12 11	
Cost of construction and repair of sledges	883 1 7	
		2,214 14 6
Cost of sledging—		
337,060 metre-gauge sleepers . .	4,607 7 6	
43,440 broad-gauge sleepers .	1,086 0 0	
6,089 6 feet deodar scantlings .	53 1 0	
3,624 10 " " " . .	45 8 0	
2,323 11 " chir " . .	43 8 0	
Price of oil and soap used in sledging sleepers	431 2 10	
Price of iron, ropes, etc., used in repair of sledge road and sledges . .	450 0 0	
Construction of dry shoot, 333 running feet	309 0 0	
Repairs to and renewals of dry shoot .	552 6 1	
Construction of water channel for use of shoot	122 0 0	
Add extra cost of launching sleepers .	559 3 0	
		8,250 4 5
GRAND TOTAL .	.....	15,778 5 2

If the timber had been carried by coolies, the expenses would have been as follows:—

	R	a.	p.
Carriage of—			
337,[illegible] metre-gauge sleepers at 1*a.* 6*p.* . . .	31,599	6	0
43,440 broad-gauge sleepers at 3*a.* . . .	8,145	0	0
6,0[illegible] 6 feet deodar scantlings at 9*p.* . . .	285	6	9
3,624 10 " " " " 1*a.* 6*p.* . .	330	12	0
2,323 10 " chir " " 1*a.* 6*p.* . .	215	3	6
Commission on above sum, R40,584-12-3 at 4 per cent.	1,623	6	3
Loss on food supply[1]	1,761	5	0
TOTAL .	43,960	7	6

The sledge road ended on the top of a high bank, 150 feet above the river's edge, and a wooden shoot was constructed to launch the sleepers. This would not have been necessary if the sleepers had been carried to the river's bank, so the cost of its construction and repairs, as well as half the cost of launching the sleepers by its means, has been added to the expenditure.

The net profit on the working of the sledge road was consequently R28,191-2-4.

[1] See page 334.

APPENDIX II.

PORTABLE FOREST TRAMWAYS IN INDIA.

THE ANDAMANS TIMBER TRAMWAY.

Extracts from a report on the Andamans Tramway (1895), by Mr. C. G. Dingwall Fordyce, then Deputy Conservator of Forests, and a report on the Andamans Tramway (1897), by Mr. E. M. Buchanan, Extra-Deputy Conservator of Forests.

Fowler's portable tramways were introduced into the Andaman Islands for the extraction of timber in the log in 1890 by Mr. E. G. Chester, then Deputy Conservator of Forests in the Andamans Forest Division.

The line adopted was system D D—*see* § 48, page 73, *et seq.*

The gauge of the line is 24 inches, the weight of the rails 18 lbs. per yard. The sleepers are trough section and are made of steel. The different sections of rails are fastened together by sole-plates and fish-plates after the Décauville pattern—*see* figure 53, page 78. The sleepers are placed 3 feet apart centrally and project 6 inches beyond the rails on either side. The tramway is suitable for manual or animal power, and in the Andamans manual labour is used.

At first, 1½ miles of railway, with the necessary switch crossings and tools for laying the line, and 10 trucks, were purchased, and the line was laid along the Dhani Khari creek along the side of an existing road and up to a forest depôt. Elephants were formerly used to drag timber over this road The tramway plant was landed on the 24th December 1890 and was working on the 10th January 1891. During the year an additional mile of tramway was bought and placed in position.

In January 1893, two miles more tramway were received, and during the same year two miles of tramway, 12 trucks and two trollies were purchased.

Portable tramways were introduced into the Andamans, where no roads exist, to take the place of dragging by elephants, as it has been found that elephants are expensive to purchase and to feed, and are at the same time very delicate, and peculiarly liable to risks of overwork, disease, etc.

Experience in the Andamans has shown that if a tramway, 3 to 6 miles long, worked by manual labour, can be kept down in the same place for a period of three or four years, and there is a sufficiency of timber to feed the line, its extraction is cheaper and altogether more satisfactory by the tramway than by elephants.

Size and weight of rails.—In the Andamans, steel sleepers are cheaper than wooden sleepers with dog spikes, as the line has to be moved so often.

Rails weighing 18 lbs. were chosen on account of the very heavy timber that has to pass over the line. Lighter rails should never be used unless the average load per truck is less than one ton; and it is necessary from the nature of the work to shift the line at short intervals, in which case the weight of the line becomes of great importance. Some of the squares transported by the Andamans tramway weigh 3 tons (of 50 cubic feet) with a dead weight of 5 tons on the axles if the weight of the body of the truck is added.

The length of the rails runs up to 21 feet. The weight of the sections of rails and sleepers may appear too great for facility of transport, and some inconvenience is certainly experienced in handling the rails; but this size of rail was advisedly chosen owing to the heavy timber which is extracted from the Andamans forests.

This tramway is capable of bearing, without any apparent strain, loads up to 3 tons in weight. But where the line is badly supported, loads which are not the heaviest put the rails out of shape at once.

Gauge.—A two-feet gauge was adopted and has been found to be suitable; the line is sufficiently stable to carry the weights taken over it. A broader gauge would only involve heavier road work; more cuttings; large and stronger bridges; more metalling and an increase in the initial cost of the tramway and rolling-stock. The cost of the up-keep of the roadway and rolling-stock and the cost of transport would also be increased without any definite advantage being gained. A narrower gauge would not give sufficient stability or strength for the heavy loads which pass over the line. A pair of trucks, forming a bogie (*see* figure 50, page 76), cannot be used round the sharp curves necessitated by the hilly nature of the country if the gauge is less than 2 feet.

Preparation of the track.—A roadway 4 feet wide is sufficient for a tramway of 2-feet gauge. If labour is cheap, it is advisable to make the track 6 feet wide to allow of men and animals passing trucks on the track at all points. The track should always be made 6 feet wide on embankments and in cuttings, as well as on curves.

It is advisable to metal the track to a breadth of 4 feet and up to the level of the top of the sleepers in localities where the rainfall is heavy or the soil soft or damp, as it facilitates work, saves labour, and ultimately decreases the cost of up-keep and repairs. It also allows of buffaloes and bullocks being used for dragging the trucks instead of manual labour only.[1] It also improves the drainage of the roadway,—a most important point to be kept in view in a country where the rainfall is heavy and often continuous, and constantly leads to landslips in cuttings. Where road metal is not available and the ground is very soft, corduroying with billets of wood may be substituted.

1 The sleepers used in the Andamans tramway are of trough section: this means that the rails are raised considerably above the level of the ground, as the sleepers themselves project 3 or 4 inches above the ground surface.

In a dry country with a hard soil, metalling becomes a minor consideration.

Drainage.—A proper system of drainage is most important in a wet country, especially if the soil is of a clayey nature and the track unmetalled. It is often advisable to cut small drains between the sleepers (which in the type of line used in the Andamans project above the surface of the ground) as water will otherwise lodge between them and cause accumulations of soft mud to form there. Unskilled natives are apt to earth up the rails along the outside in such a way that the ground between the rails becomes water-logged.

A proper system of side drains is also most important, and measures must be taken to ensure their being always kept open.

A broad, fairly deep inside drain, from which cross-drains branch at frequent intervals, is one of the best ways of keeping the track dry on a hill-side. In cuttings, side drains have been given up in favour of central drains which run between the rails of the line and below the sleepers.

Laying the line.—The sleepers should be placed 3 feet apart centrally. The way in which the rails are fastened to the sleepers has been described in detail in § 48, page 73, *et seq.*

The joints of the rails should not be opposite to one another. A small space should be left between the ends of the rails to allow for the expansion of the metal. The holes bored in the fish-plates by which the ends of the rails are joined together are constructed so as to allow of this being done.

The sleepers should not be placed under the fish-plates, which help to unite the different lengths of rail together, because if this is done it is impossible to bolt the clips, which fasten the rails to the sleepers, properly owing to the fish-plates being in the way.

On an unmetalled road the sleepers should be packed with stone as soon as they are laid.

In bending rails, the rail bender should be applied along the rail every 9 or 12 inches, so that the rail is bent gradually and evenly without sharp corners. Unskilled workmen, left to themselves, are apt to make sharp sudden bends at long intervals, and so to give the line the appearance of running round a series of crooked corners. The bending of the rails should be done away from the joints as much as possible. If a joint must be bent to preserve regularity in a curve, the fish-plates should be beaten to shape first and then clamped to the bent ends of the rails.

After a rail is bent, it should be fixed into the sleepers, and the companion rail can be bent until it fits accurately into the clips at the opposite ends of these sleepers.

When the line is being laid, trucks carrying the necessary supply of rails, sleepers, bolts, etc., should come up along the portion of the line that has been laid.

It is often necessary to bend the fish-plates; this can be easily done, with a heavy hammer, on the ground.

When unskilled labour is employed, it is most important to see that the

sleepers are laid at right angles to the rails. A siding should be laid down every 1 or 2 miles to allow of trucks passing one another.

Curves on or to bridges should be avoided, and the approaches to either end of a bridge should be, as far as possible, dead level.

Curves.—The sharpest curve round which loaded trucks have been worked by men in the Andamans has a radius of 25 feet. The sharpest curve should not have a radius of less than 30 feet, and then only if single trucks are used and these are moved at a walking pace. If possible, curves should be laid down with a radius of 50 feet or more, and if this be done, no extra precautions are necessary to prevent the trucks leaving the line. The only precaution used in laying the line round curves in the Andamans, to prevent derailment, is to slightly raise the outer line of rails.

Sharp curves are avoided wherever possible, as they involve a great risk of derailment, increase the wear and tear on the rails and rolling-stock, and strain the motive-power considerably.

Gradients.—The *maximum* gradient for a loaded truck going *uphill* is 3 in 100, the most economical 2 in 100. Any gradient of more than 1½ or 2 in 100 should be used for short distances only.

If possible, all gradients should be kept under 2 in 100. This has been found most economical both for men and buffaloes where it is not possible to have a perfectly level road.

For *downhill* work, gradients should not exceed 4 or 5 in 100, and these gradients should be used in the case of manual labour only, where sufficiently powerful brakes are available, and then only for short distances and not on curves or bridges. The maximum down gradient where buffaloes or bullocks are used is 3 in 100. The best gradient for downhill work is from 1 to 2 in 100. This will allow a loaded truck to move of itself or nearly so, and to be controlled easily by the brake or by four men holding on to a rope behind.

The steepest gradient permissible for a loaded truck without a brake is under 1½ in 100.

Experience has shown that so long as the line is level or uphill, buffaloes are better than men as a motive-power. But if there are steep downhill gradients (3 in 100 or more) men are better than animals, as four men can keep a loaded truck moving downhill much better under control than one brakesman and a pair of buffaloes, as the brakesman has to guide the draught animals in addition to manipulating the brake.

Nature of trucks used.—Very strong, heavy, *single* trucks are used in the Andamans, consisting of a framework of timber strengthened by two iron tie-rods, which carries a strong wooden platform (*see* fig. 64, page 102). Oil axle-boxes are fastened to the undersurface of this framework to receive the journals of the axles of the wheels. The wheels are slotted on to the axle and cannot move independently of it. A flat iron plate is fixed on to the top of the wooden platform. A T-shaped fork or iron frame, working on a bolt centre, is provided for each truck and can be fixed into the centre of the platform if it is required to use a pair of trucks as a bogie-wagon.

The trucks should always be worked down together, so that all the men are available to help the more heavily loaded trucks over difficulteis or up steep gradients where necessary.

A light passenger trolly, which can be lifted off the line by two men, is necessary to allow of a proper supervision of the line, as it is necessary to inspect the line frequently to see that everything is in order.

The wheels are made separate from the body of the trolly. The trolly consists of a light framework with a moveable back for the seat, and two handles for the trollymen.

Brakes.—The trucks were received from Messrs. Fowler & Co. without brakes. For gradients up to 2 in 100 an ordinary single lever brake was found sufficient to control loaded trucks.

Screw brakes were not considered satisfactory, as the mechanism was apt to be in the way and if damaged could not be repaired locally, and moreover would have been more expensive in the first instance.

Lever brokes, with the handles below the platform of the trucks and still within easy reach of the brakesman, were found absolutely necessary. It was also found to be a *sine quâ non* that the brake should be simple, with few parts or joints, and yet effective.

The brakes actually used in the Andamans were designed by Messrs. Fordyce and Buchanan, and have been found to work satisfactorily. They are at the same time simple and have no joints. The brakes are worked from the side of the trucks. No brakes applied at the end of the trucks have been found effective, and now when the trucks are loaded the men are forbidden to go in front of them. The brakes have been described in detail in § 70, page 101, *et seq.*

Load and motive-power.—The amount of the load carried depends to a great extent upon the gradient of the line, whether the gradients are frequently changed, or whether they are long and continuous, and also upon whether the road is metalled or not.

On the level, with a good road and good curves, the *maximum* load which can be placed on one truck drawn by 4 men is 3 tons, but the *economical* load would be only 1½ tons.

When working loads up a gradient of 2 in 100, the *maximum* load is about 1½ tons and the *economical* load one ton. The same loads could be taken down a gradient of 3 in 100 with good brakes.

On the level or uphill, one buffalo with one brakesman can drag two laden trucks easily, thus doing the work of 8 men, and saving 7 men on every two trucks.

In the Andamans, men and buffaloes are used as the motive-power for moving the trucks. Four good men are sufficient for the working of one truck, including loading and unloading. The trucks travel at the rate of about two miles an hour. A pace exceeding an ordinary walking pace should not be allowed.

Four men will push a loaded truck over an ordinary line a distance of 6 or 7 miles a day, returning the same evening with the empty truck.

In choosing between men and draught animals, the greater initial cost of laying a line for animals to work over must not be forgotten, as the track must be well metalled. The cost of maintenance will also be greater.

Whatever the motive-power, it is always advisable to work as many trucks as possible together, as then the men on the several trucks can help each other in loading the trucks in succession.

Length of logs extracted.—The length of the logs extracted varies from 12 to 24 feet. Some logs have been taken out 50 feet long on bogie trucks, but only over the straight and level portions of the line. The length of the logs extracted varies inversely as the girth, so that a long log is not heavier than a short one, in fact the reverse is usually the case.

Long logs have a tendency to oscillate and to throw the trucks off the line, and consequently it is advisable to place the larger end on the front portion of the truck, so as to prevent the wheels jumping off the line.

As a rule each log rests on one truck only and consequently the length of the log does not influence the laying out of the curves.

Financial and practical advantages of the tramway.—In the Andamans where no roads exist, labour is scarce, contractors not available, where elephants have to be imported at a great cost and all operations have to be carried out by Government agency, while the nature and climate of the country are such that dragging is a slow process, and the distances over which timber has to be transported are considerable, it has become imperative to supplement the use of elephants, both on account of the time and expenditure saved, by wheeled traffic. This gives us a choice between carts and tramways.

The original cost of construction, as well as of up-keep of cart-roads in a climate such as the Andamans, where metalling and frequent repairs are necessary, is such as to prohibit the use of carts on a large scale for the extraction of timber. More especially is this the case, as the initial cost of carts, buffaloes, and bullocks, as well as their up-keep, is extremély high in the Andamans, where everything must be imported.

Portable tramways have consequently been found cheaper and better than cart roads and carts in localities where no roads exist.

Export of timber by tramway is more certain and quicker than that by carts; a greater volume of wood can be carried over a tramway in a given time than either by cart transport, or by elephant dragging.

An elephant with one mahout and two grasscuts can drag, on an average, one ton (50 cubic feet) a day (5 days a week) over an average distance of 1½ miles. The animal has to be fed, its attendants paid, and rough tracks made for the extraction of the logs.

With carts, unless 6 are worked together, extra men would be required for loading the logs. A cart with one pair of bullocks will on an average work out one ton of timber a day over a variable distance according to gradients and condition of the road, but rarely exceeding 4 or 4½ miles. One man per cart only is then required, but other men have to be kept for cutting

grass; stabling has to be provided and the animals fed; accidents and delay are frequent, especially if the gradients on the roads are steep or if the road surface is in bad condition.

On tramways with 4 men to a truck, working 6 trucks together, a ton of timber (including loading and unloading the trucks and bringing the empty trucks back) can be hauled over a distance of 6 miles a day, as long as only low gradients have to be worked over.

Some elephants are indispensable for dragging the timber from the place where it is felled to the nearest road, tramway or waterway. But the process is a slow one, and necessitates more labour than either carts or the tramway.

The initial cost of carts and cattle is less than that of the portable tramway for the export of a given volume of wood. But when the cost of the construction, metalling and up-keep of a wide road is taken into consideration and compared with the simple process of preparing a narrow track and its comparatively small cost of up-keep, laying the tramway (which is portable) on it, and the saving in cost of extraction and labour, the balance is in favour of the tramway so long as it can be kept in one position for 3 or 4 years, is from 3 to 6 miles long, and provided sufficient timber can be brought to it to keep it fully employed.

The cost of making a cart road and the time required for its construction are both very much greater than that which is necessary for the preparation of a tramway track, and when once the working has passed to another part of the forest, the use of the road as a means of transport ceases to exist, whereas the tramway can be taken up and used elsewhere.

The cost of one mile of tramway, including switches and a few timber trucks delivered at the Andamans, and of making the track and laying the line, is R8,000 per mile. The average cost of preparing the track and laying the line is R400 a mile. These figures are based upon the cost of the 1½ miles of tramway laid down by Mr. Chester in 1890.

In the year 1892-93, the 24 elephants employed on dragging logs hauled 6,191 tons of timber over an average distance of 1½ miles; this is as nearly as possible 250 tons per annum each: in other words, one elephant hauled, on an average, 42 cubic feet or ⅚th of a ton of wood per diem over a distance of 1½ miles. This timber was subsequently carried over three miles of tramway. The tramway thus saved three miles of elephant dragging, which means that if the tramway had not been laid to get out the same volume of timber, the number of elephants would have had to be increased in the proportion of two elephants for every one employed in dragging timber to the terminus of the tramway.

Fourteen elephants on an average were employed daily in drawing logs to the terminus of the tramway, so that had there been no tramway, 28 more elephants would have been required to do the work done by the tramway.

The original cost of an elephant in the Andamans is R4,000 and it can do ten years' work, so that the capital involved (allowing interest at 5 per cent.) to purchase an elephant costing R4,000 would be R10,560.

The interest on this sum at 5 per cent. is R528; if to this the cost of feeding the elephant, cutting dragging paths, gratuities to attendants, share of elephant doctor, chains, gear, etc., be added, the annual cost of maintaining an elephant will come to R1,159 and the cost of keeping 28 additional elephants R32,452, and this sum has been saved by constructing the three miles of tramway.

From this must be deducted—

	R
The cost of loading and railing 14 logs a day for one year	2,088
Up-keep of the line	1,000
Depreciation at 10 per cent. on cost of rail material on R26,760	2,676
TOTAL	5,764

which leaves a profit of R26,688 per annum. From these figures it is clear that the Andamans tramways pay well, and it would be impossible to work the forests without them. Again, if more elephants were available for hauling logs to the terminus of the tramway, a larger quantity of timber could be railed over them and the profit would be still larger.

Maintenance.—The cost of maintenance of the Andamans tramway, although the line is subjected to a comparatively large amount of traffic, in wet and dry seasons alike, has never been more than about R300 per mile per annum. The deterioration of the line after 6 years' work is not appreciable, but there is some wear on the rolling-stock and loss of bolts and fish-plates, for the renewal of which an expenditure of 10 per cent. per annum of the original value of the stock must be allowed.

PORTABLE TRAMWAYS IN THE MADRAS PRESIDENCY.

Portable tramways are being used for the transport of fuel in the Kothapatham Casuarina plantation, and the Sriharikota Range of the Nellore District, Central Circle; and in the Tamenapatam Casuarina plantation in the North Arcot District; while timber in the log is transported by its agency in the Anamalai Reserve of the South Coimbatore District.

ANAMALAI TIMBER TRAMWAY.

Extracts from a Report on the Anamalai timber tramway, by Mr. J. W. Cherry, Conservator of Forests, Southern Circle, Madras Presidency.

This tramway is situated on the lower slopes of the Anamalai hills in the South Coimbatore District, and is 42 miles by road distant from the nearest railway station (Podhanur). The mean annual rainfall (2 years) is 47 inches. The last 3 miles of this road rise 1,000 feet above the plains, which are themselves about 1,100 feet above the level of the sea. The tramway runs *downward* from the top of this *ghât*-road into the forest, so the logs have to be

taken up hill. The timber is still carried down to the plains from the top of the *ghat* in carts.

Elephants are employed to bring the timber from the places where the trees are felled to the tramway.

The locality is feverish, and water is scarce for six months out of the twelve, so that the working season is limited to six months, and even then it is difficult to get labour or even to maintain the forest establishment.

The logs have to be brought up from the forest to the top of the *ghât* so that it would be impossible to adopt a sledge road.

Nature and gauge of the portable tramway adopted.—The gauge adopted for the tramway was 24 inches.

The motive-power is chiefly bullocks, but for a short time elephants were used. Transport by elephants proved to be considerably cheaper than that by bullocks, but as a sufficient number of elephants were not available, this motive-power had to be given up in favour of bullocks: one, two or three pair of bullocks are used according to the size of the logs to be transported. The tramway was constructed (see figures 43 and 44, page 70) of steel rails, weighing 14 lbs. per running yard, laid on patent corrugated steel sleepers fitted with wrought steel chairs, which are riveted on to the full width of the sleeper. The rails are fixed to the sleepers by steel hook-headed bolts.

Single sleepers are placed at intervals of 3 feet 9 inches along the rails, and double sleepers (*see* figure 44, page 70) are placed at the ends of the rails so as to join one rail to another. The single sleepers are 3½ inches broad, the double ones 7½ inches. The sleepers are 30 inches long.

The head of the rail (greatest width) is 1 inch wide; the rail 1¾ inch high; the shank is 0·2 inch thick, the base is flat and 2¼ inches wide.

Plant.—The plant consists of 7 miles (1888-89) of portable railway suitable for animal power as described above; five crossings; one portable turntable, 3 feet diameter; one weighing machine, 3½ feet square; twelve pairs waggons (see figure 50, page 76); one tool box; four eccentric tongs; a quarter of a mile curved sections of assorted lengths of radius of 30 feet; four self-acting switches; six brake cars (1889-90); one portable hand crane on truck (2½ tons) (1890-91); two portable hand cranes (3 tons) (1891-92); one rail-bending machine; 1,000 spare clutch bolts; and duplicate parts or trucks.

Mr. Cherry describes the plant as simple, well-made, and easily put together, and states that the first quarter of a mile of the tramway was laid in three days by inexperienced labour; that the rails came out separately from the sleepers, and that no difficulty was experienced either in fixing the rails on to the sleepers, or in putting the trucks together; that the sections of the line are easily moved from one place to another by coolies, under the superintendence of a forest guard; and that the sleepers and trucks seem to stand any amount of rough usage, but that the trucks are perhaps rather stronger and heavier than is necessary for the work for which they are required; and that 14 lbs. rails have been found to be too light for the transport of timber; and that rails weighing from 20 to 25 lbs. would have made the tramway much firmer and would render the working easier.

Cost of Tramway.—From a statement prepared by Mr. Cherry, it appears that the cost of the tramway delivered at the site where it was to be erected was R60,839-12-2; this includes the cost of repairs to the plant (R243-12-6) up to the end of 1892-93. R10,608-12-3 were spent on improving the old cart-road on which the tramway was laid, but this sum does not include the cost of making the road in the first instance.

The cost of carriage of the plant from London to Madras was 11·3 per cent. of the original cost in London, and that from Madras to the Anamalai Range was 20·4 per cent. of the cost of the plant delivered at Madras.

The cost of the tramway laid down, including the cost of the plant, the preparation of the road, and the putting down of the tramway, was therefore R10,206-15-2 per mile. The cost of the tramway and rolling-stock was R8,691-6-7 a mile.

Construction of the Tramway.—No difficulty was found in fixing the rails to the sleepers, or in putting the different parts of the trucks together. The tramway was laid down by Mr. H. J. Porter, Deputy Conservator of Forests, assisted by Messrs. Marshall and Moss, Extra-Assistant Conservators.

The track on which the tramway was to be laid was completed in 1887-88, and the line was put down at the rate of 3 miles a year. It was found that 2 miles of the track were unsuitable for a tramway, as the gradients on it were too steep; so the line on this section was taken up, and the actual length of line open to traffic was 5 miles.

Gradients.—The total rise on the tramway is 669 feet, the length of the line being 5 miles and 200 yards, so that the mean gradient of the whole line is approximately 2½ in 100 or 1·25 degrees. The steepest sections on the line are shown in the following table together with their lengths:—

Number of sections.	Average length of each, in feet.	Total length, in feet.	Gradient.	Angular equivalent. Degrees	Angular equivalent. Minutes.	Remarks.
18	97	1,746	1 in 14	4	0	Gradients taken with a Ceylon road-tracer.
18	97	1,746	1 in 13	4	24	
5	100	500	1 in 12	4	45	
5	100	500	1 in 11	5	0	
4	100	400	1 in 10	5	45	
1	50	50	1 in 7	8	0	

Experience has shown that all the above gradients are too steep to allow of the tramway being worked economically by bullock power, and that if the tramway is to be worked economically by bullock power, the gradients

must be so arranged that one pair of bullocks shall be able to draw large logs weighing two or three tons (54·64 or 81·96 maunds) up the steepest incline.

On the present line two or three pairs of bullocks can with difficulty take one log, weighing more than one ton, over the line in a day. In order to allow of one pair of bullocks hauling logs weighing two tons up a tramway, the steepest gradients must nowhere exceed 1 in 15 or $3^\circ 49'$, and if possible should be kept as low as 1 in 20 or $2^\circ 52'$.

Brakes.—Great difficulty has been experienced in obtaining a reliable brake to check the velocity of the loaded trucks when descending steep gradients on a tram line. The separate brake-vans at first sent out proved useless. Some side-lever hand brakes subsequently received to be fitted to the bogie trucks themselves were not very much more effective and were flimsy and imperfect. These hand brakes required more than one man to keep them on the wheel, and even then it was found that when the line was slippery, the wheels skidded along the rails without gripping. Mr. Bryant, Deputy Conservator of Forests, has rendered these side-lever brakes more effective by applying a screw power to them, but even now they are not reliable.

Mr. Cherry is of opinion that a hand brake similar to that used in working a winch or crane, applied by screw power to the upper portion of the tyres of the wheels, will alone prove effective, and has suggested that this should be tried.

Curves.—The rail-bending machine which had been ordered was found to be broken on arrival, so that only the curves supplied, which were of a radius of 18 feet, could be used, and experience has shown that these curves are much too sharp. The result of having such sharp curves has been the constant derailment of the trucks when going round them. The following measures have been adopted with a view to removing this difficulty and with marked success. The outer rail on the curves has been raised 1½ inch above the inner one, so as to throw the perpendicular from the centre of gravity of the loaded truck towards the inner port ion of the curve, and the roadway at the curves has been well ballasted. A second rail was added along the inner side of the curve, so as to increase the grip of the flanged wheel on the rails. The addition of this second or guard rail along the inner edge of the curves has had the desired effect, and derailments are now of rare occurrence.

Motive-power.—It was intended to use bullocks as the motive-power at the time that the tramway was purchased and they are now used to haul the laden trucks. In 1889-90 elephants were used instead of bullocks for hauling large logs up the tramway. An elephant was found to do as much work as nine bullocks, and can draw heavy logs which cannot be taken out by bullocks. One elephant took out a log containing 108 cubic feet solid on a pair of waggons in one day over a distance of 3½ miles. The average daily load was 58 cubic feet solid for a whole month, while a fair load for one day was 75 cubic feet solid. The elephants were used twenty days in the month.

The elephants could not, however, be spared from their other work of dragging the logs to the tramway from the places where the trees were felled, so that bullocks had again to be employed as the motive-power.

The result of the experiment of using elephants as a motive-power shows that the cost of extraction of logs along the tramway, so long as the steep gradients on the road exist, is much decreased by their use.

In 1889-90, the average cost of extraction of timber by elephants was 2·84 pies per cubic foot solid per mile, while that extracted by bullocks cost 4·4 pies per cubic foot solid per mile. It should also be noted that the elephants could haul the largest logs, while small or medium sized logs only could be extracted through the agency of bullocks.

The elephants did not do (so far as it could be ascertained) any material damage by walking on the rails and sleepers, but since the brakes were unreliable, there was considerable danger of the loaded trucks on the steeper gradients running on to and so injuring the elephants.

The above cost of extraction is deduced from the volume of timber removed per mensem, and the monthly cost of keeping the elephants or bullocks, and does not include the initial cost of the animals used.

Comparative cost of extraction by carts and the tramway.—The extraction of logs by carts before the tramway was laid down cost, so far as can be now ascertained, 5 pies per cubic foot solid per mile.

The cost of extraction in 1889-90, when elephants were used, was 2·84 pies per cubic foot solid per mile, and by bullocks during the same year 4·4 pies per cubic foot solid per mile.

In September 1892, after some of the steepest gradients had been reduced—and the steepest gradients on the tramway were as detailed on page 348—Mr. Cherry found that the cost of extraction by bullocks over the 5 miles of line then in use was 2·6 pies per cubic foot solid per mile, and the contractor stated that if the present steep gradients were reduced to between 1 in 15 (3° 49′) and 1 in 20 (2° 52′), he would contract to take the timber out at a rate of about 1·6 pies per cubic foot solid per mile.

Capabilities of extraction.—It has been estimated that with twelve pairs of waggons worked to the fullest extent possible, 113,000 cubic feet solid of timber could be extracted annually. The average annual volume extracted during the four years, 1889-90 to 1892-93, inclusive, is only 36,256 cubic feet, the largest annual outturn being 56,100 cubic feet.

Conclusions—

(1) The maximum up-gradient allowable on tramways for bullock power is 1 in 15 (3° 49′). The load which can be drawn up a tramway is fixed, as in the case of ordinary cart roads, by the weight which can be drawn up the steepest gradient on it.

(2) The mean up-gradient should not exceed 1 in 25 (2° 18′).

(3) The sharpest curve permissible is one whose radius is 60 feet, but where the ground is suitable, the curves, especially where the gradients are steep, should have a radius of 100 feet. The curves should be bent as required, and no set curves should be got from the manufacturer.

(4) Where the road can be laid permanently, wooden sleepers are better suited than the steel ones supplied by the manufacturers where large logs have to be transported.

(5) Rails weighing 14 lbs to the running yard are not suitable for lines where heavy logs are to be extracted. Rails[1] weighing 20 to 25 lbs should be used on all semi-permanent or permanent parts of the line.

(6) Where the curves have a radius of less than 60 feet, a guard-rail should be added along the inner side of the curve, and the outer rail should be raised 1½ inches above the inner one.

(7) On gradients of more than 1 in 15 (3° 49'), the ordinary brake supplied by the manufacturers is not sufficient, and a special brake is necessary, but a suitable one has not yet been found.

(8) The financial results are not likely to be favourable unless the portable railway is utilized to its fullest extent.

(9) Bullock power is well adapted as long as the up-gradients are lower than 1 in 20 (2° 52'), in which case one pair of bullocks can haul logs weighing up to 2 tons (54·64 maunds).

Fuel Tramways in the Nellore District.[2]

Two portable tramways (Messrs. Fowler and Co.'s) are used for carrying fuel in this district, one at the Tamenapatam Casuarina plantations and the other in the Sriharikota Range. The Casuarina plantations stretch along the sea shore within a distance of from 1 to 3 miles from the Buckingham Canal. Sriharikota is an island about 35 square miles in extent and the forest consists of indigenous trees. These reserves are situated about 45 miles from Madras and supply the greater part of the fuel consumed in that city.

The tramway was first introduced in 1885, and since then the plant has been gradually increased, until now there are 9¾ miles of tramway, and all the fuel extracted from these two reserves is transported by its agency. Previous to the introduction of the tramway, the fuel had to be carried to the canal side by country carts, and as the supply of carts obtainable was limited, the cost of extraction by their agency was very heavy.

Nature of the soil.—The soil both at the Casuarina plantation and at Sriharikota is pure sand. In the latter forest the ground is more undulating, and cuttings have been made through the sand banks so as to keep the gradient low. It has been found that owing to the lightness of the tramway and the loose nature of the soil on which it is laid, it is impossible to keep the line in good order, as the rails shift and throw the line out. The steel sleepers have been let into wooden Casuarina sleepers, and three such sleepers are placed under each section, 15 feet long; this has rendered the line more stable, but unless the steel sleepers are bolted on to the wooden sleepers, perfect rigidity cannot be obtained.

[1] See Board of Revenue (Madras), No. 128 Forest of 27th February 1894.
[2] Mr. H. B. Brougham, Deputy Conservator of Forests, Madras Presidency.

Description of the tramway.—The line is one of Fowler's portable tramways (see page 68 *et seq*). The gauge of the line is 24 inches; the rails weigh 10 lbs. to the yard. The line is practically level except where it is intersected by sand dunes, when gradients as steep as 1 in 12 (4° 45') are allowed, but must on no account exceed 200 yards in length. The weight of a section 15 feet long with four sleepers (3 single and 1 double one) is 134 lbs. The rails are in lengths of 15, 12, 9, 6, and 4 feet. The sleepers are placed at intervals of 3 feet 9 inches. Sugarcane wagons, type J. (fig 49, page 75) are used for the transport of the fuel, and the wagons are drawn by coolies, two coolies being allowed to each truck. These wagons carry from ¾ to 1 ton of fuel. They are 3 feet 9 inches high, exclusive of the wheels, and 5 feet long. Bullocks were first tried, but were found to be unsuitable. The number of trips made by the coolies in a day depends entirely upon the distance. If the lead is one mile, one set of coolies can make four trips a day. The wagons are not provided with brakes, nor are they required.

Cost of the tramway.—The original cost of the tramways is as follows:—

		R
Casuarina Range, 4 miles	. . . .	21,045
Sriharikota Range, 5¾ "	. . . .	24,699
	TOTAL .	45,744

The above includes R10,942, being the value of 2½ miles of line received from North Arcot in 1894, which, with the exception of the rails and sleepers, were unserviceable.

Financial aspect.—Financially, the tramway is a success. If it could be worked steadily for 20 days a month, 200 tons of wood could be carried to the Buckingham Canal monthly.

The actual cost of transport of fuel by tramway compared with that by country carts is shown in the following table:—

Forest.	Rate per ton per mile by tramway.	Cost of transport of 100 tons of fuel.	Rate per ton per mile by country cart.	Cost of transporting 100 tons of fuel.	Difference in favour of tramway.
	R a. p.	R a. p.	R a. p.	R a. p.	R a. p.
Casuarina Plantation . . .	0 [illegible]	11 [illegible]	0 12 0	75 0 0	6[illegible] 8 0
Sriharikota Forest .	0 3 0	18 12 0	1 0 0	100 0 0	81 4 0

Note.—A country cart can carry only half a ton of casuarina wood at a time, and it cannot make more than two trips a day. The cart hire for one cart-load of fuel over one mile is 6 annas. The wagons can make four trips over a mile of tramway, carrying at each trip one ton, and the cooly charge, including loading and unloading, is 4 annas per cooly per diem. Two coolies per truck are employed.

A ton of fuel is made up of 400 pieces of wood. The country carts carry at Sriharikota only 200 pieces, and the cart-hire per mile is 8 annas. Not more than two trips

can be made by country carts per diem. The trucks on the tramway make four trips of a mile each, carrying 1 ton at each trip. The coolies at *Sriharikota* are paid 2 annas per ton transported.

The following table shows the financial state of the tramways since their introduction. This shows that there has been a net saving of Rs20,453-12-3 in the case of the Casuarina Plantation, irrespective of the depreciation value of the stock at 6 per cent. and interest at 4 per cent. on the capital. There has been a loss of Rs961-7-9 on the Sriharikota tramway, which would have been turned into a profit if the tramway had been worked up to its possibility :—

Casuarina Plantation Range.

Year.	Length of the tramway used, in miles.	Quantity transported to the canal, in tons.	Cost by tramway including depreciation of stock and interest on capital outlay.		Cost by country carts.		Difference.
			Rate per ton, per mile.	Total cost.	Rate per ton, per mile.	Total cost.	
			R a. p.	R a. p.	R a. p.	R a. p.	R a. p.
1884-85	1½	1,591	0 7 11	1,056 5 3	1 0 0	2,127 0 0	+1,070 10 9
1886-87	2	2,036	0 6 8	2,346 9 11	1 0 0	4,957 7 2	+2,610 13 3
1887-88	2	No wood was extracted this year.					−569 14 1
1888-89	2	2,665	0 5 7	1,970 6 0	0 14 0	4,569 2 0	+2,098 10 0
1889-90	2½	501	1 0 10	1,455 15 3	0 14 11	1,292 2 6	−164 12 9
1890-91	2½	2,471	0 3 10	1,597 0 1	0 12 3	5,076 1 6	+3,479 1 5
1891-92	2½	1,613	0 5 1	1,422 7 5	0 13 5	3,719 12 4	+2,297 4 11
1892-93	2½	1,530	0 5 0	1,584 12 3	0 13 11	4,384 10 0	+2,799 13 9
1893-94	3½	1,925	0 5 5	1,859 6 8	0 14 5	4,670 3 0	+2,810 10 4
1894-95	4	1,323	0 5 1	1,686 6 4	0 14 6	4,807 13 0	+3,121 6 8
TOTAL .	...	15,671	...	14,950 9 2	...	36,004 3 6	+20,453 12 3

Sriharikota Range.

Year.	Length of tramway used, in miles.	Quantity transported to the canal, in tons.	Cost by tramway including depreciation of stock and interest on capital outlay.		Cost by country carts.		Difference.
			Rate per ton, per mile.	Total cost.	Rate per ton, per mile.	Total cost.	
			R a. p.	R a. p.	R a. p.	R a. p.	R a. p.
1889-90	2½	137	2 8 7	859 3 10	0 1 10	39 3 11	−819 15 11*
1890-91	4½	1,820	0 4 9	2,432 12 9	0 1 10	1,731 0 0	−701 12 9
1891-92	4½	543	0 7 9	2,048 15 9	0 3 8	985 0 0	−1,063 15 9
1892-93	4½	2,724	0 3 7	2,782 5 5	0 3 9	2,915 2 6	+132 15 1
1893-94	4½	2,748	0 4 1	3,167 3 11	0 5 3	4,072 4 0	+905 0 1
1894-95	5½	3,414	0 3 7	3,064 8 11	0 4 3	3,650 14 5	+595 5 9
TOTAL .	...	10,825	...	14,365 0 7	...	13,403 8 10	−951 [illegible] 9

* The tramway worked only for one month during the year.

CHANGA MANGA FUEL TRAMWAY.

Decauville's system of portable tramways has been used at the Changa Manga Plantation[1] since May 1884, when the Forest Department purchased the tramway and rolling-stock imported by Messrs. Robson & Co., of Lahore, who had purchased the fuel standing the previous year.

The gauge is 16 inches (0·40 metre). The length of the tramway now in use is 4 miles; of this total, 5,133 feet were purchased second hand from Messrs. Robson & Co., 2,500 feet were bought from the manufacturers in 1884-85, 5,280 feet in 1885-86 and the balance in 1891-92.

The rails are riveted on to the steel sleepers and cannot be detached from them. The sleepers supplied with the rails first bought were not flat, the central portion was embossed (see figure 51, page 78), and they were the same length as the gauge of the tramway. Those received more recently are of channel section, 3½ inches wide, and have been found to be very much stronger, the former are constantly broken, whereas the latter have never been known to break.[2] The sleepers project 2 inches on either side of the rails.

The bottom of the rails is flat, while the head is rounded in the usual manner. The width of the head of the rail is three-fourths of an inch, that of the base being 1½ inch, while the rails are 1½ inch high. The rails are riveted to steel sleepers 3½ inches wide and ¼ inch thick. The distance between the sleepers from centre to centre at the end of a section is 3 inches, that between the next two 33½ inches, and that between the others 39⅜ inches.

The sections of the tramway are made in three lengths, in straight as well as in curved pieces, namely, 16⅜ feet (5 metres), 8¼ feet (2½ metres) and 4⅛ feet (1¼ metres). The arrangement for joining the sections is the same as that described on page 71.

The fish-plates and sole-plates are from 2 to 3 inches long, and are fastened to the rails by one rivet.

The sections are not riveted together.

The weight of the rails used is 4·50 kilos per metre or 9 lbs. per yard.

Two kinds of trucks are in use (see figures 55 and 56, page 81); those of the old type were bought from the contractor, while the new kind were purchased in 1885. The axles of the old type of truck were not sufficiently strong to carry the weight of the fuel; and have since been replaced by axles, axle-boxes, and wheels similar to those supplied with the new type of truck, and are now quite serviceable. The old type of truck is provided with an iron frame similar to that shown in figure 55. The framework of the truck itself, to which the axle-boxes which carry the axles of the wheels are attached, is 3 feet 3½ inches wide, while the long iron cradle in which the fuel is placed is 3 feet 10 inches wide, 5 feet 2½ inches long, and 2 feet 9 inches high.

The new type of truck is 4 feet 7½ inches long, and 2 feet 1⅜ inches wide. Pieces of stout angle iron, 2 inches wide and ¼ of an inch thick, are bolted

[1] Changa Manga working-plan and note on the tramway, by Munshi Fazl-ud-din Khan Bahadur, Extra-Assistant Conservator of Forests.

[2] Mr. B. O. Coventry, Assistant Conservator of Forests.

to the narrow end of the framework of the truck at each corner and keep the fire-wood in position. This piece of angle-iron projects 2 feet 11 inches above the framework of the truck on which the fuel rests.

The wheels, axles and axle-boxes are the same in both types of truck. The wheels are fixed to the axles in such a manner that they cannot be separated from them by any of the appliances which are available at the plantation itself. The diameter of the wheel is 1 foot 1 inch, the thickness 2 inches, the flange is 1½ inches deep. The axles are 1½ inches in diameter. An empty truck of the old type weighs 636 lbs., while one of the new type weighs 558 lbs. There are 13 trucks of the old type and 26 of the new one.

The plantation is divided up into blocks and compartments by cleared lines, along which the line is laid.

The whole plantation is on a practically level plain, so that the whole of the tramway is nearly level. The steepest gradient is now only about 1 in 100. The curves used are those sold by the manufacturers. The sharpest permissible is one with a radius of 30 feet; trucks can be worked round curves with a radius of 10 feet by hand, but if bullocks are used as a motive-power on these curves, the wagons are often derailed.

No brakes are required on the trucks. Bullock power is the motive-force employed.

The tramway is laid down along any the compartment lines that may be convenient. The sections are fitted on to one another by placing one of the ends furnished with a sole-plate in contact with the end of another section fitted with two fish-plates and pushing the sections together, so that the fish-plates come one on either side of the thin neck of the rail. The rails are in practice not riveted together, and a slight space should be left between them to allow for the expansion of the metal under the influence of heat, and to prevent their buckling. The line is laid down along the compartment lines at the beginning of each working season (or altered as may be necessary), so that the mean distance from the annual coupe to the railway station, where the fuel is sold, shall be as short as possible, and temporary branches are laid down the middle of those compartment lines on either side of which the fuel is stacked.

A permanent establishment of one forest guard and three beldars is employed in looking after the tramway. It is their duty to keep the rails properly laid, adjust them when they are pushed out of the straight line by the rolling-stock, to pack the line with earth in order to ensure smooth running, and to look after the tramway generally. A blacksmith is also kept permanently at Changa Manga to repair the trucks, etc.

The distance over which the fuel has to be carried varies considerably with the part of the plantation which is being worked, as the plantation runs along the railway line for a distance of 2 miles and stretches for a distance of nearly 3 miles to the south of it. The greatest distance over which fuel will have to be carried is 4½ miles and the mean distance for the whole

plantation 1¼ miles. The mean annual volume of wood carried over the tramway during the ten years ending 31st March 1893 was 759,170 cubic feet stacked of thick billets (*i.e.*, over 2 inches in diameter) and 242,020 of thin billets (*i.e.*, under 2 inches in diameter), both 5 ft. long. One hundred cubic feet stacked of dry shisham, in thick billets, 2½ feet long and over 2 inches n diameter, weigh 3,198 lbs. (39 maunds), and 100 cubic feet stacked of thin billets, 2½ft. long, weighs 820 lbs. (10 maunds).

A pair of bullocks draw a load of three trucks loaded with thick billets (over 2 inches in diameter) which weigh 3,198 lbs. or 39 maunds per 100 cubic feet stacked. A truck contains 34 maunds of fuel, so that the load of fuel of thick billets (weighing 3,198 lbs. per 100 cubic feet stacked, which can be drawn by two bullocks) is 102 maunds or 8,364 lbs.

The number of trips that can be made in one day depends upon the distance to be traversed, the time of the year, and the weather. When the distance was from 1 to 1½ miles, five trips were made on an average during the longer days, and three trips during the shorter ones. In 1893 the distance which the fuel had to be carried was 3 miles or more, and in consequence only two trips could be made when the days were long and one when they were short. In December and January only one trip a day is made on account of the shortness of the day, and during July and half of August when the mosquitos and flies are very troublesome.

When two trips a day are made, 6,760 cubic feet stacked of fuel can be carried daily from the coupe to the railway station when all the trucks are in use. One hundred cubic feet stacked of dry fuel in billets, 5 feet long, weighs on an average 25 maunds, and when green (freshly-cut) 30 maunds of 82 lbs. each.

When all the trucks are in use, 13 pairs of bullocks are employed, so that a pair of bullocks will carry on an average 520 cubic feet stacked of fuel, a distance of 6 miles a day. One hundred cubic feet stacked of dry fuel, chiefly shisham (*Dalbergia Sissoo*), weighs, according to experiments made at Changa Manga, when cut up into billets 5 feet long of all classes in the proportions found in the fellings, 25 maunds (2,050 lbs.). That is to say, that one bullock can carry 31,980 lbs. of fuel over one mile in a day.

A cart with four bullocks can only make one trip a day over the same distance that trucks can be drawn twice, both for long and short distances, and the average load of a four-bullock cart is 200 cubic feet stacked or 50 maunds (4,100 lbs.).

A statement of the work done by the tramway since it was introduced in 1884, up to the end of March 1899, is shown in tabular form on page 358. From this statement it appears that the amount of fuel carried by its agency, reduced to cubic feet solid carried over one mile, is 11,924,994.

The tramway, was originally worked by Government bullocks, but this was found to be unsatisfactory. It is now worked on contract. The contractor carries the fuel from the forest to the sale depôt and re-stacks it

[1] Mr. C. B. O. Coventry, Assistant Conservator of Forests.

there. He is paid according to the distance that the fuel is carried at the following rates :—

For a distance averaging less than 2 miles—

(1) For thick billets, i.e. over 2 inches in diameter, R1-9 per 1,000 cubic feet stacked.

(2) For thin firewood, i.e. under 2 inches in diameter, R1-5 per 1,000 cubic feet stacked.

For a distance over 2 miles but not exceeding 4 miles—

(1) For thick fuel (over 2 inches in diameter) R2-1 per 1,000 cubic feet stacked.

(2) For thin fuel (under 2 inches diameter) R1-12 per 1,000 cubic feet stacked.

The work by contract is very satisfactory as it renders supervision by the Forest staff unnecessary.

Statement of work done by the tramway since its introduction at Changa Manga.

Years.	Quantity, in cubic feet, solid, carried.	Distance carried, average (miles).	Equivalent quantity, cubic feet, solid, carried one mile.	Working expenses, including repairs.	Interest at 4 per cent. per annum.	Estimated wear and tear.	Total cost.	Cost of carrying 100 cubic feet, solid, one mile.	Length of tramway, in miles, and its capital cost, as well as price of rolling-stock.		Remarks.
1	2	3	4	5	6	7	8	9	10	11	12
				R	R	R	R		Miles.	R	
1884-85 . . .	352,260	1·18	414,424	2,371	1,080	1,373	...	...	1¼	9,665	Up to 1893 the forest official year ended on 31st March; after that year it ends on 30th June.
1885-86 . . .	287,280	1·18	337,976						1	7,748	
1886-87 . . .	353,555	1·11	395,007	1,541	694	937	...	...	...	...	
1887-88 . . .	91,380	0·67	61,225	349	694	937	...	...	...	...	
1888-89 . . .	468,269	1·20	559,978	1,350	694	937	...	...	...	...	
1889-90 . . .	64,099	2·21	141,460	417	694	937	...	...	1½	9,303	
1890-91 . . .	120,834	2·58	311,752	445	694	937	...	...	...	1,103	
1891-92 . . .	39,572	2·96	1,167,933	2,124	1,076	1,512	...	...	...	...	
1892-93 . . .	393,133	3·61	1,419,210	2,118	1,120	1,400	...	...	...	...	
April to June 1893 .	82,742	2·75	227,540	507	250	350	...	...	...	...	
1893-94 . . .	372,239	3·25	1,210,107	2,002	1,120	1,400	...	...	...	...	
1894-95 . . .	316,832	3·75	1,183,120	2,315	1,120	1,400	...	...	...	...	
1895-96 . . .	332,725	4·10	1,364,185	2,976	1,120	1,400	...	...	...	...	
1896-97 . . .	294,968	4·50	1,327,356	3,458	1,120	1,400	...	...	...	...	
1897-98 . . .	292,817	4·20	1,250,113	2,070	1,120	1,400	...	...	...	...	
1898-99 . . .	431,614	1·25	539,518	2,617	1,120	1,400	...	...	...	...	
TOTAL .	4,651,172	...	11,924,994	28,810	16,520	18,220	...	...	4	27,817	

The cost of transporting this amount of fuel is briefly as follows :—

	R
Interest on the capital at 4 per cent.	8,145
Estimated wear and tear on the tramway and rolling-stock at 4 per cent.	11,220
Working expenses	14,170
	33,535

or very nearly R0·92 per 100 maunds (of 82 lbs.)

The whole of this fuel was extracted from Blocks I, II, III and IV. The average cost of carting the fuel, at the normal rates, from Blocks I and II is R3 per 1,000 cubic feet stacked (equivalent to 330 maunds), the average distance being 1¼ mile. The average distance of Block III from the railway station is 2¾ miles, and the average carting rate per 1,000 cubic feet stacked is R5-8. These rates are equivalent to R0·73 and R0·67 per 100 maunds per mile, as contrasted with R0·92 per tramway.

The average cost of extraction of fuel by carts from Blocks I, II and III is R0·68 per 100 maunds per mile, so that the actual loss in using the tramway during the years 1884-85 to 1892-93, both inclusive (nine years), is R8,002 or R889 per annum.

The indirect benefits which result from the tramway, however, more than compensate for the actual pecuniary loss incurred on its working, and it is certain that if the Department had to rely upon country carts only for the extraction of all the fuel which is grown in the plantation, the rates of carriage would rise to as much, if not more, than those now paid for the fuel carried by the tramway; and as nearly all the carts employed in the plantation belong to the agricultural population of the surrounding villages, it would be absolutely impossible to obtain country carts at those seasons of the year during which the bullocks are employed in cultivating the fields or in removing the agricultural produce. There are very few non-agricultural cartmen near Changa Manga, and these are nearly always employed in the transport of grain and other agricultural produce, for which they are paid much higher rates than they get for fuel.

The fuel can be extracted by the tramway in half the time that it could be carried by carts with the same bullock power, so that at Changa Manga, where the number of cattle and carts is limited, twice the amount of fuel can be extracted in a given time by means of the tramway than could be extracted by carts, and by thus reducing the time required for the extraction of the fuel by one-half, the establishment are enabled to devote much more time to the important duties of irrigating and protecting the plantation generally.

The employment of the tramway ensures the prompt and punctual delivery of the fuel at the railway station, and thus increases its value and improves its position in the market. Prompt and punctual delivery can never be ensured as long as carts only are used.

In 1897-98,[1] during the Tirah campaign, it was impossible to obtain any carts, and had the transport of fuel been dependent on this means of

[1] Mr. B. O. Coventry.

transport, practically no fuel could have been carried; and as the fuel is usually sold in the coupes before it is carried to the railway station, great trouble and pecuniary loss would have resulted.

Possibility of extraction by the tramway.—With the 39 trucks in stock in constant use at one time up to date, 3,120 cubic feet stacked of fuel can be removed at one time to the station. So that even if the fuel is being brought from the most distant part of the plantation, in which case two trips can be made for 8½ months and one trip only for 3½ months (see page 356), 6,240 cubic feet stacked per diem for 3½ months and 3,120 cubic feet per diem for 3½ months (1,151 maunds or 42 tons for 8½ and half this amount for 4½ months) can be extracted. This is equivalent to 1,176 tons per month of 26 working days, or 13,058 tons, or 357,865 maunds, or 1,073,591 maund-miles, or 1,450,761 cubic feet-miles per annum, if the tramway is worked to its utmost capacity.

APPENDIX III.

A EUROPEAN FOREST TRAMWAY.

Extract from the journal of a tour through the Continental forests of Europe in 1893, by Mr. J. Copeland, Deputy Conservator of Forests, and notes made on a visit to the Sihlwald in 1898, by Mr. C. G Rogers, Deputy Conservator of Forests.

THE SIHLWALD FOREST TRAMWAY.

The tramway in the Sihlwald is used for the carriage of fuel and timber from the different parts of the forest to the railway station of Sihlwald on the Sihlbrugg-Zurich line. The forest officer's head-quarters and the shops for sawing up the logs, cutting up the wood into fuel, manufacturing tool handles, etc., etc., are near the station of Sihlwald.

Gradients.—The tramway is laid out with a down gradient throughout (there are no up gradients on the line), so that the fuel and logs come down the line of their own weight and the empty trucks only have to be dragged up to the line to the place where the timber or fuel is cut.

The best gradient for this tramway is from 2 in 100 (0°43') to 3 in 100 (1°9'). The maximum gradient allowed on the principal line is 6 in 100 (3°26'). On the more temporary lines into the coupes of the year, steeper gradients are allowed, but the gradient on these lines should not, if possible, exceed 5 in 100 (2°52'). Loads have been taken down considerable lengths of line with a gradient of 7 in 100 (4°), but experience has shown that this gradient is too steep and that good brakes and men skilled in their use and who do not loose their heads are required if the gradient exceeds 5 in 100 (2°52'). For short distances (200 feet), gradients of as much as 11 in 100 (6°45') have been adopted, but only in most exceptional circumstances, as it is very difficult to control the speed of a loaded truck on such steep inclines even with the best of brakes.

If the gradient on the line does not exceed 2 or 3 in 100, no brakes are necessary, but as soon as the gradient exceeds this amount brakes become necessary. Practically brakes are necessary on all tramways in hilly districts.

Steep gradients are dangerous in the autumn when the lines are wet and slippery and overgrown with grass; at this time of the year sand is put on the rails to keep the wheels from slipping.

Alignment.—The track should be aligned with a down gradient of 2 or 3 in 100, and this slope is only departed from when the natural obstacles met with on the line render this absolutely necessary, and then a down gradient

of 5 in 100 should never, if possible, except for short distances, be exceeded; steep gradients should always be succeeded by almost level sections, in order to allow of the speed of the loaded trucks being checked quickly.

Gauge.—The gauge of the tramway is 2 feet (60 centimetres).

Type of line.—The tramway used is manufactured by Harmann and Sons of Osnabruck, Hanover. The tramway resembles the Décauville type in that the rails are fixed inseparably to the sleepers. The method of joining the sections of the rails to each other is different, and the outside flange of the foot of the rail is wider than the inside portion of the flange (*i.e.* the head of the rail is not vertically above the centre of its foot). This is said to add very materially to the stability of the line and to prevent derailments on sharp curves.

Weight of the rails.—The rails weigh 12·07 lbs. per yard (6 kilos. per metre). Her Forst Rath Meister considers that rails weighing 22·15 lbs. per yard (11 kilos. per metre) are heavy enough for the transport of any log.

Curves.—The minimum radius of curve allowed is 46·71 feet (15 metres). Curves with a radius of 62·28 feet (20 metres) are bought from the manufacturers and are used generally; curves of smaller radii are constructed locally. On curves the outer rail is raised slightly, the amount of superelevation being from ½ to 1 inch (1 to 2 centimetres) according to the radius of the curve.

When the ground will not allow of a curve of a radius of 15 metres being constructed, zig-zags are substituted for curves to allow of the line being taken round the corner, and simple points are used.

Preparation of the track.—The road on which the rails are laid is well raised above the ground and is well drained. The track is ballasted with gravel, and where this is not procurable in very damp places, the line is laid on billets of spruce firewood.

Laying of the line.—On the more permanent portions of the line, the rails are laid on wooden sleepers, as it is found that the track when laid on wooden sleepers is more stable than the line supported by the steel sleepers sold with the rails.

The length of the sleepers varies from 39·37 inches to 49·21 inches (1 metre to 1·25 metres); the dimensions of the sleepers vary from 5·9 inches wide and 3·5 inches deep (15 and 9 centimetres) to 4 inches and 2·36 inches (10 and 6 centimetres). The broad sleepers are placed at the end of the rails where two rails are spiked on to one sleeper, and the intermediate sleepers are narrower.

The rails are fastened to the sleepers by iron spikes. Two spikes fasten each rail to each intermediate sleeper, and each end of each rail is fastened by two spikes also. The rails are fastened to each other by fish-plates. The distance between the sleepers from centre to centre varies between 27·6 inches and 31·6 inches (70 to 80 centimetres). The rails fixed on to steel sleepers cost R2 68 per yard (4·50 francs per metre), including the curves and points. The preparation of the track cost R515 a mile (50 centimes per metre).

For permanent lines, where wooden sleepers are used, the rails cost R2·2 per yard (3·80 francs per metre), including the cost of laying down the sleepers, but not the value of the wood.

Rolling-stock.—Only the wheels and brackets are bought from the manufacturer, the framework of the trucks is made of wood locally. The wheels are fixed inseparably to the axles. Experience has shown that it is much cheaper to make up the trucks locally than to buy those sold by the manufacturers. The brackets have a rectangular slot in them which fits over the axle of the wheel. Blocks of soft metal are placed in the slot to prevent the axle being worn away. These blocks of soft metal can be renewed as required. Two pairs of wheels and brackets cost R115 to R128 (180 to 200 francs)[1], and the wooden framework costs R32 (50 francs).

Brake.—The brake used on the Sihlwald forest tramway has been described in detail on pages 103 to 106, to which reference should be made. The brake must be applied to the trucks at the commencement of the steeper gradients so as to reduce the velocity at which the trucks move; the wagons must never be allowed to get out of control, and they must always move slowly; as soon as they begin to move at all fast the brake should be applied and the speed reduced.

Motive-power and load.—The trucks move down the line in virtue of their own weight, or may be drawn by bullocks, if the trucks are provided with brakes. Bullocks cannot be used if the gradient exceeds 6 in 100 (3° 26′). One bullock can haul three wagons containing 3 stères of fuel each, that is a load of 3,300 lbs. (1 stère = 500 kilos.). A bullock will walk 25 miles a day (40 kilomètres) half with the full load and half taking back the empty trucks. In winter, on account of the rain, the load weighs ⅓rd more than that given above.

A man can bring down two trucks containing from 141·16 to 211·74 cubic feet of logs (4 to 6 cubic metres). The logs are placed on the trucks as in figure 50, page 76; the man stands on the hinder truck and manipulates the brake so as to control the speed of the descending load. The speed should be sufficiently low to allow of the brakesman bringing the trucks to rest wherever he likes. One man was seen to bring down a load of six logs, each 19·7 feet (6 metres) long and about 3 feet in mean girth.

Cost of carriage.—Before the introduction of the tramway, the extraction of the firewood cost R3·84 per 100 cubic feet solid (1·80 francs per stère[2]). It is estimated that the cost of extraction, including the wear and tear on the rails and rolling-stock, is nearly 6 annas per 100 cubic feet solid (0·19 francs per stère).

[1] 25 francs = 16 rupees.
[2] 1 stère = 33 cubic feet solid.

APPENDIX IV.

INDIAN EXAMPLES OF WET SLIDES.

1. THE MANDHOLE SLIDE.

The first wet slides constructed in India was made at Mandhole in the Jaunsar Forest Division of the North-Western Provinces, and was finished in the spring of 1872. The length of the slide was 21,280 feet, and the vertical fall 2,658 feet. The mean gradient was practically 5 degrees (1 in 11½).

The gradients on the slide varied between 3 degrees and 18 degrees. The slide was made of three chir (*Pinus longifolia*) planks 12 feet long, 12 inches wide and 5 inches thick, the interior measurements of the trough being 12 inches wide by 7 inches high. The sleepers were brought to rest at the end of the slide by widening its base out into a fan-shaped table, 42 feet long and 12 feet wide at the lower end. The lower end of the table was raised about 1 foot above the level of the end of the slide. A sleeper took 20 minutes to travel the whole length of the slide. The sleepers were launched at the head of the slide at the rate of one a minute. Only ½ per cent. of the sleepers were damaged in transit.

The slide was used up to the end of 1873, and 82,000 sleepers passed down it.

The initial cost of the slide was R13,700, or R3,414 per mile, the annua cost of repairs amounted to R720. The net profit on the Mandhole slide and tramway was R24,525.

2. THE PABAR SLIDE.

The Pabar slide at Lambatach was made in 1872. Its length was 6,332 feet, the total fall being 2,687 feet. The gradients on the upper portion of the slide varied from 6 to 20 degrees, and those on the lower portion from 25 to 44 degrees. The direction of the slide was straight for the greater portion of its course, and the curves that were necessary were very gentle. The lower portion of this line was virtually a dry slide.

The slide was covered in, so as to prevent the sleepers from leaving it. The inner dimensions of the trough were 11 inches by 5½ inches. The planks forming the cover of the trough were fastened to it by light wooden frames placed at intervals of 3 or 4 feet.

The sleepers were shot out of the end of the slide into a pool of water kept at a constant depth of 5 feet. The pool was formed by damming up a branch of the Pabar river. A stream of water was allowed to run along the further edge (from the end of the slide) of the pool, and the sleepers were carried away from the end of the slide by this means into a channel from which they were lifted out and stacked, and were thus prevented from accumulating in the pool itself.

The slide was used up to the end of 1873, and 120,082 sleepers were taken down it. The number of sleepers damaged in transit amounted to only 2 or 3 per cent. The cost of sending sleepers down the slide was R1 per hundred. The primary cost of the slide was R8,472, or R7,064 per mile. The cost of repairs was about R700. The net saving in cost of carriage of the sleepers by means of the slide, instead of upon men's backs, was R9,772.

3. The Deota Slide.

The Deota wet slide[1] was commenced in 1876 and finished in 1878. The principle of construction was the same as that of the Mandhole slide. The slide followed along the bed of the Bagiâr stream, but its construction presented many more difficulties than either the Mandhole or Pabar wet slides on account of the numerous precipices and landslips which had to be crossed or avoided. The length of the slide was 12,192 feet and the difference in elevation between the highest and lowest point of the slide was 1,300 feet. The gradients of the slide varied between 5 and 22 degrees. The most suitable gradient was found to be 15 degrees. The slide itself was made of chir planks 12 feet long, 13 inches wide and 5 inches deep, the inside dimensions of the trough being 13 inches wide and 8 inches deep. The slide was constructed for the transport of sleepers 8½ inches wide and 4½ inches deep. The necessary supply of water was introduced from the Bagiâr stream by means of troughs placed at distances of about a quarter of a mile apart. A little water was found necessary even on the steepest gradients to prevent the slide from being set on fire by the friction between the sleepers in motion and the slide itself.

Where the gradients are less than 20 degrees, water is necessary to help the sleepers to move down the slide. The slide could only be worked during the rainy season on account of the small supply of water available at other times of the year. The sleepers were launched at the rate of two a minute, and took 10 minutes to reach the bottom of the slide, a distance of 2½ miles. When a sufficient supply of water was available, 1,200 sleepers could be worked down in a day of 10 to 12 hours. Ten chowkidars were kept along the slide to regulate the water-supply, remove any boulders which might fall into the slide, and to look out for landslips. One carpenter was also permanently employed in executing petty repairs and in tightening up those wedges which had worked loose.

The slide ended in a fan-shaped table similar to that used at Mandhole. The sleepers were either stacked on the bank of the Tons river or shot straight into it, according as the river was suitable or unsuitable for the launching of sleepers.

This slide was entirely destroyed by a great flood on the 9th August 1889, with the exception of a length of 660 feet in some rice-fields near the river Tons. The mass of mud and water which came down the Bagiâr stream must have been from 40 to 50 feet deep in places, and not only swept away the slide and 12 men who were sleeping under a rock near the head of the

[1] Report on the Deota Sledge Road by Mr. E. McA. Moir, Deputy Conservator of Forests, 1885.

slide, but entirely changed the configuration of the bed of the stream. The bodies of these men were never found.

The initial cost of the slide was R26,000, or R11,555 per mile. The cost of repairs up to 31st March 1885 was R7,988, or about R591 per mile per annum.

The slide itself, as well as the bridges and supports, was made of chir (*Pinus longifolia*) and was expected to last six or eight years, but owing to the impossibility of keeping the slide constantly wet, the wood only lasted three or four years, and consequently the whole of the woodwork of the slide and its supports was renewed at least once after its first construction.

The beams of the bridges were renewed with kail (*Pinus excelsa*), deodar (*Cedrus Deodara*) or tun (*Cedrela Toona*) when the chir beams had become rotten. Considerable inconvenience was occasioned several times by the sudden collapse of a bridge in the middle of the working season.

The net saving, up to the time that the slide was entirely destroyed, was R20,000, and 570,000 sleepers were worked down it. The direct saving in transport by means of the slide, including the annual cost of repairs, was 1 anna 3 pies per metre-gauge sleeper.

Consequent on the absolute destruction of the Deota slide, the construction of wet slides has been abandoned in Jaunsar, except in localities which are specially suitable to their construction, and sledge roads have superseded them (latterly inclined wire ropes have been tried).

The advantages of sledge roads over wet slides in a district like Jaunsar, where the rainfall is heavy, may be epitomised as follows:—

(1) That slides can rarely be made for any considerable length, either in one straight line or with a constant gradient, without a very large initial expenditure, and that, unless these conditions can be complied with, wet slides have not been found to work satisfactorily.

(2) That the working of a wet slide requires a great deal more supervision than that of a sledge road.

(3) That the proper working of a slide is dependent on a sufficient supply of water, and that it has been found very difficult to regulate the supply of water required on the different parts of the slide.

(4) That the slide must follow, more or less closely, the course of a stream in order to obtain the supply of water necessary for its proper working, and is in consequence liable to be seriously injured, if not entirely destroyed, by an unusually high flood. If the supply of water is limited, as it generally is in the upper valleys of the Himalaya, the slide can only be used for thee thre or four months during which heavy rain falls, and remains idle for the rest of the year.

(5) That it is extremely difficult to keep the slide water-tight, and that unless the slides are kept permanently wet the joints will open out and cause the slide to leak badly. The passage of the sleepers

down the slide, especially round curves, loosens the wedges which keep the bottom and sides of the slide together and causes it to leak considerably.

(6) The annual cost of repairs of a wet slide is much greater than that of a sledge road.

4. Wet Slides in the Mandi State.

The following remarks on the construction and working of a wet slide in the Mandi State forests are taken from Colonel Bailey's note on the export works of the Mandi Forest Company, Punjab, published in the "*Indian Forester*" for May 1889, page 173, *et seq.* :—

The slide which was made in 1888 generally resembles those in use since 1872 in the Jaunsar Division of the North-Western Provinces. It was designed to last four years, and is made of fir (*Abies Webbiana or Picea Morinda*). The sides of the trough in which the sleepers move are 2½ inches thick, while the bottom is only 2 inches thick. The general width of the slide is 13 inches, but this is increased to 15 to 20 inches, according to the radius of the curve given to the slide, in order to allow the sleepers to move round the curves freely.

The trough is supported on wooden trestles (see figure 83, page 134), the heads of which are from 2½ to 3½ feet long and 12 to 15 inches in diameter; the legs of the trestles are made of fir poles 3 inches in diameter at their smaller ends. The small ends of these poles are let into the head of the support. The legs are spread outwards to give rigidity to the structure. Some of these trestles are as much as 30 feet high.

The trough is laid in sections 12 feet long, which are joined upon the trestle supports; lighter intermediate trestles are introduced at intervals of 6 feet. Where the supports of the trestles are tall, the bottom and sides of the trough are made to break joint, in order to give the slide more rigidity. The base of the trough slants inwards on curves, so as to reduce the force with which the descending sleeper strikes against the outer side of the trough. The gradient of the slide varies from a dead level to a fall of 40 in 100, or about 23½ degrees; the latter slope can only be used for very short distances when absolutely necessary.

The legs of the trestles will, if carefully placed, resist a flood of water about 6 feet deep. Where there is no good resting place for the lower ends of the trestles in the bed of the ravine, they are mortised into horizontal poles placed 3 feet apart across the chasm above which the slide is taken.

The slides are not continuous, but are made in lengths of about half a mile, the sleepers being received into a pool, the top of which is level with the head of the portion of the slide below. Mr. Fendall, by whom the slide was designed and made, considers that the system of constructing a series of comparatively short slides has a great advantage over the usual method of constructing one long one, in that there is less difficulty in obtaining a sufficient supply of water for the proper working of the slide; and

also that if one of the sections of the slide is damaged in any way the scantlings can be carried by men over the broken section of the wet slide while it is being repaired, and the other sections can still be used for the transport of the scantlings. The sleepers or scantlings do not attain so great a velocity when the sections of the slide are short, and in consequence do not damage the sides of the trough nearly so much.

The actual construction of the Mandi wet slide is described by Mr. Le Marchand as follows[1] :—

In the first place, plane the edges of the bottom boards, as well as the inner portion of the side boards where they touch the bottom boards. Then drive your wedges home so as to tighten the whole structure. Then pass a saw down both sides of the bottom board so as to give it a rough edge; having done this, loosen your wedges, ram moss in as tight as you can, and then finally tighten up your wedges. One of the block supports should be placed in the middle of each section (they are 12 feet long) ; if this is not done, you will never get the moss to stay in its place.

[1] The "*Indian Forester*," Volume XIV, page 553

APPENDIX V.

INDIAN EXAMPLES OF WIRE-ROPE WAYS.

1. ALAGAR HILL EXPERIMENTAL WIRE-ROPE.

The Alagar Hill reserve is in the Madura District of the Madras Presidency. The rope used was an old one, constructed of strands of steel wire twisted round a central hempen cord, and was three-eighths of an inch in circumference. The rope was used for carrying fuel across a steep valley. The wire at the upper end was attached to a windlass and at the lower end to a post embedded in the ground. The span was 900 feet, and the mean gradient 9½ degrees. The carriers consisted of iron blocks furnished with a grooved wheel which moved along the rope, and a hook fastened to a pin which passed through both sides of the block. The bundle of firewood was

FIG. 159.

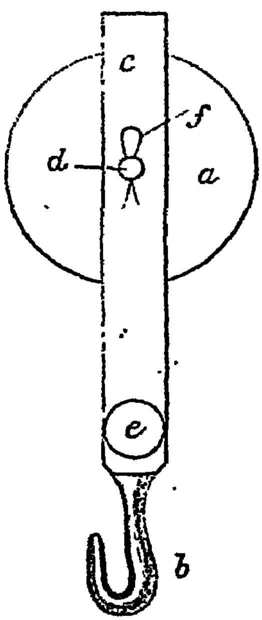


FIG. 160.

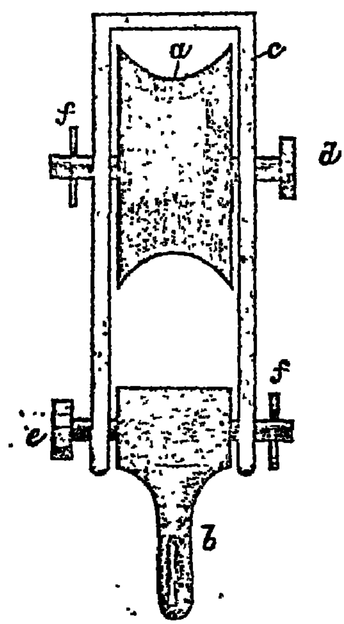


Figure 159 is a side elevation of the carrier used for the transport of fuel at Alagar Hill, Madura District, Madras Presidency: a *is the pulley which runs on the inclined wire rope;* b *the hook to which the firewood is attached;* c *is the iron frame which carries* d, *the pinion on which the pulley rotates;* e *is the pin to which the hook is attached;* f *is the piece of wire which keeps the pins in position. (Drawn by Mr. H. Gass.)*

Figure 160 is an end elevation of the same carrier, the letters used are the same as in figure 159. (Drawn by Mr. H. Gass.)

attached to this h ook. The runners were very roughly made and cost R2 each. At first, loads of 100 lbs. and subsequently of 75 lbs. were slid down the rope. The wire soon broke at a point about 350 feet from the lower end. The total quantity of wood slung across it was 193 tons. In one day 14·40 cart loads of 2 tons each (54·64 maunds) were taken across it. In an hour, using 12 carriers, 3,000 lbs. (7·20 tons) were run across. The loaded carriers could be sent down in 8 minutes and were carried back by coolies in twelve minutes, by which time twelve new loads were ready for despatch. In working the rope, six men on 4 annas, and six women on 2 annas a day were employed, and taking 14½ cart loads as a fair outturn for a day, the cost of transport by the wire rope would be 2½ annas a cart load. If the same quantity had had to be carried on coolies' heads, no man could have transported more than 100 lbs. an hour, or more than half a cart load in a day, if so much even; so the cost of transport would have risen to 8 annas a cart load. The saving in the actual cost of transport was 5½ annas a cart load, or 11 annas a ton, and on the whole 193 tons, R132. This is the saving in the *actual cost* of transport and does not include the initial cost of the wire, or of placing the rope in position.

2. BAMSU EXPERIMENTAL WIRE-ROPE WAY.

The sleepers which were cut in the Bamsu deodar (*Cedrus Deodara*) forests were carried down a wet slide first, then over a sledge road along the valley of the Bamsu stream and through a gorge to the edge of some very precipitous ground. A sledge road had been made from the bottom of this precipitous section to the river Tons. The sleepers were conveyed from the lower end of the upper sledge road to the upper end of the lower sledge road by means of a wire rope. The configuration of the ground (see figure 161, page 373) is such that it was not considered possible to use one long span, so three separate spans, arranged so as to take the sleepers round the hill side, were erected. The lengths and gradients of the spans are shown in the accompanying table:—

Span.	Length of rope, in feet.	Mean gradient, in degrees.	Gradient of steep upper portion.	Gradient of less steep lower portion.	Vertical fall, in feet, taken by an aneroid barometer.
Upper	634	26	29¾	20	274
Middle	759	31¼	36	25	402
Lower	432	27	29	23	205

It will be noticed that the upper two-thirds of the span has a much steeper inclination than the lower one-third; the former is greater, and the latter less, than the mean inclination.

The rope was erected in March 1894 and is one of Bulivant's patent steel wire hawsers, three-quarters of an inch in diameter, which has a breaking strain of 9 tons, and weighs ¾ lbs. per fathom (6 feet). Blocks of wood of moru oak (*Quercus dilatata*), about 2½ inches square and 7 to 8 inches long, were used as carriers. A notch, 1¼ inches deep and three-fourths of an inch wide, was cut in the carrier to fit on to the wire rope. Two eyes of iron wire were fixed on to the sides of the block (see figure 90, page 157).

FIG. 61.

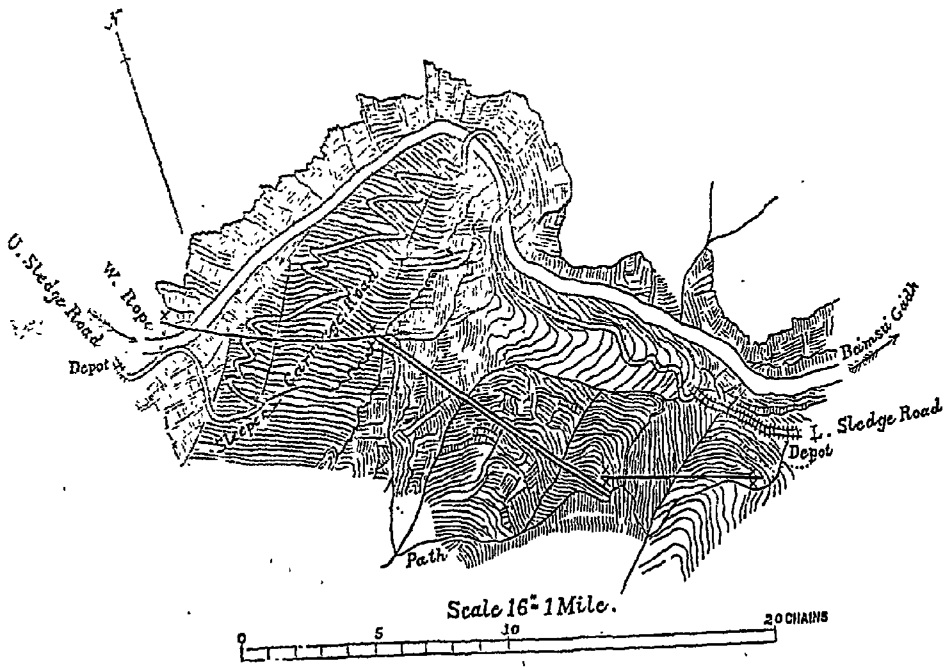


FIG. 162.

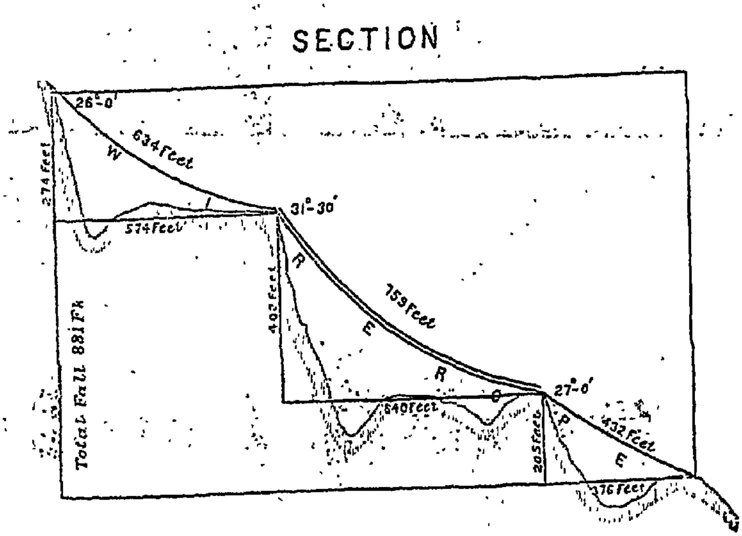


Figure 161 is the plan of the Bamsu inclined wire rope, and figure 162 is a vertical section, showing the position of wire ropes used.

A loop of wire is fixed on to one eye, and ends in a hook which can be placed into the other eye. A piece of rope is fastened round the middle of the sleeper, so that it hangs freely in a horizontal position. The wire loop is passed through the rope which is fastened round the sleeper and is then hooked on to the eye of the block. The sleeper is thus suspended in a horizontal position from the block. It is launched broadside on by two men. When a sleeper travels down in this position it comes to rest or is moving slowly by the time it reaches the bottom of the span. If it moves down end on, it reaches the lower end with considerable velocity and impinges upon some poles placed in a slanting position to stop it. The lower end of the fixed rope passes over a pole placed horizontally and is then wound round a windlass by means of which it can be tightened or loosened. The upper end of the rope is fastened round a beam supported on a wooden framework (see figure 84, page 147) and is then passed two or three times round a tree and the end securely fastened.

The wooden blocks are burnt during their passage down the wire rope. If the notch is burnt straight up the block, it can be used for three trips down each of the three spans of the rope way. A piece of wood is then fixed in the notch and the block can be used for three more trips. Sometimes the notch does not burn straight and the blocks do not then last so long.

Occasionally the sleepers fall off the rope owing to the notch burning towards one side and the block splitting in consequence. The iron portion of the block can be used several times. The average cost of a block is half an anna.

The blocks are carried by men up to the head of the inclined wire ropes when a sufficient number have reached the bottom of the slide. Fifteen men are required for the working of the inclined wire rope, three at the top of the first span, four at the top of the middle span, four at the top of the third span, and two at the bottom of the third span, with one man in charge, who usually is at the head of the second span. The men at the top of the second and third spans remove the sleeper from the rope by unhooking the loop, carry it to the head of the second or third span, as the case may be, fix it on to the inclined rope and let it go down. The load is one metre-gauge sleeper (weight 60 lbs.). Broad-gauge sleepers (weight 180 lbs.) were tried, but were found to reach the bottom of the middle span with such a velocity as to damage themselves considerably.

Two hundred and fifty sleepers on an average can be sent down the whole length of rope (1,825 feet) in a day, so that the actual cost of transporting a hundred sleepers (including the cost of the wooden blocks) would be as follows:—

	R	a.	p.
Cost of 10 wooden blocks	0	5	0
Cost of wire ropes or hemp for attaching sleepers to wooden blocks	0	4	0
Cost of sliding sleepers	2	1	0
Sundries	0	2	0
TOTAL	2	12	0

The cost of carrying sleepers on men's backs from the bottom of the upper sledge road to the top of the lower sledge road would be 10 pies each, or R5-3-9 per hundred.

The initial cost of the wire rope (1,825 feet) delivered at Bamsu and placed in position was R817-9.

The middle span was converted in 1895 into an endless moving rope. The endless rope passes round two grooved wheels, placed one at either end of the span, the plane of the wheels being that of the mean gradient of the span.

Two cradles were immoveably tied to the moving rope at equal distances apart, so that when the loaded carrier reached the lower end of the span, the empty one arrived at the upper end. The grooved wheels were 4 feet in diameter. The nave of the wheel was 13 inches in diameter and strengthened by iron straps 1 inch wide and ¾ inch thick, fastened near either end. An iron rod of 1¾ inch wide was passed through the middle of the nave and rounded off where it projected on either side of it, and formed the axle on which the wheel rotated. The ends of the axle worked in sockets fixed into the horizontal beams of the framework which supported the wheels.

The brake used consisted of a bar of wood fixed to the ends of two levers which had their fulcrums bolted on two posts embedded in the ground. This bar was pressed against the under surface of the wheel when it was required to moderate the speed of the descending load or to bring it to rest. The brake was applied by two men.

The endless rope after leaving the grooved wheel at the upper end of the span passed over two iron wheels to prevent its rubbing against the ground, and at the lower end it passed over a log placed horizontally against the framework of the grooved wheel. These iron wheels were the cause of the rope breaking, and Mr. Osmaston is of opinion that had they been replaced by wooden rollers the rope would have carried 500,000 sleepers without breaking. In reality the rope broke after 33,000 sleepers had passed over it.

The cradle took four metre gauge sleepers, two placed on either side of the moving endless rope.

The saving effected was 2 pies per sleeper.

[1] Babu U. N. Kanjilal, Extra-Assistant Conservator of Forests.

APPENDIX VI.

EUROPEAN EXAMPLES OF WIRE-ROPE WAYS.

ARBEDO WIRE ROPE.[1]

At Arbedo near Bellinzona (on the St. Gothard Railway), an inclined wire rope is being used for the extraction of firewood. It consists of two absolutely straight parallel fixed wire ropes to carry the produce down and the empty carriers up, and of an endless movable guide-rope below these running round a drum at the top and at the bottom, by means of which the loads are controlled. The rate at which the guide-rope moves is controlled by powerful steel band brakes, lined with wood, acting on the sheaves at either end. The loads can be stopped at any point on their downward course by bringing the guide-rope to rest. Several loads travel down the fixed wire rope at the same time.

The loads are brought to the top station by means of radiating auxiliary cables leading from the different parts of the forest. These auxiliary cables are simple fixed wires and are worked without any brake arrangement; the loads rush down them at a terrific pace and are brought up against a thick bank of earth.

The length of the fixed rope is 9,354·8 feet (2,850 metres) and cost R6,000 (10,000 francs, taking R15 = 20 shillings and 5 francs = 4 shillings) including the cost of erection which amounted to R1,080 (1,800 francs). The average gradient is 29 per cent. or 16½ degrees; the minimum gradient varying from 28 to 36 per cent. (15¾ to 19¾ degrees) and the maximum gradient from 45 to 50 per cent. (24¾ to 26½ degrees). The circumference of the fixed wire rope is 2 inches, that of the guide-rope 1¾ inches.

There are 11 intermediate supports. The difference in altitude between the top and bottom of the inclined wire rope is 2,175 feet, as determined by an aneroid barometer. The diameter of the brake wheel is 2 feet. The average number of loads on the fixed wire rope at one time is 13. The average weight of a load is from 275 to 330 lbs. (125 to 175 kilogrammes). The wheels of the carriers are grooved, 5 inches in diameter 1¼ inches thick, the groove ¾-inch deep. Two such carriers are attached to each load. The intermediate supports consist of two uprights with a cross-piece (b), fig. 163, through which the two iron hooks (a), which support the two fixed inclined cables, are fixed. The end of these hooks (c), figure 164, is grooved to take the fixed ropes, and unless the fixed wire ropes were absolutely straight, they would be dragged off these hooks.

[1] Mr. H. J. Porter, Deputy Conservator of Forests.

FIGURE 163.

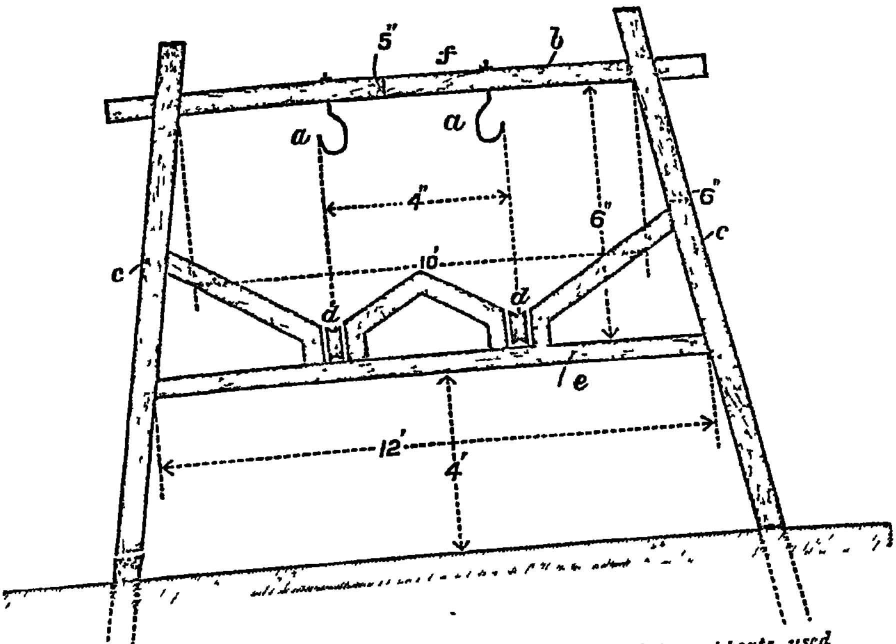


Figure 163 shows in elevation one of the intermediate supports used on the Arbedo inclined wire rope; a a are the hooks on which the fixed wire ropes rest. These are bolted to a horizontal beam f, which is nailed to two stout inclined uprights c and c, which are in their turn firmly embedded in the ground. The carriers which run on the fixed wire rope have been omitted. The guide rope runs on the wheels d d, which work in sockets fastened to a second horizontal beam e, and is thus prevented from touching the ground. Scale 4 feet = 1 inch.

A cross-piece is placed below the hooks which carry the fixed wire ropes, and to this two wheels are fastened vertically below the fixed wires. The moving guide rope passes over these wheels and is thus kept from dragging along the ground. The fixed wire ropes are perfectly rigid and look like iron bars; but the guide rope is more or less flexible and hangs down in a succession of curves and is only drawn up to the fixed ropes where they pass over the supports. At these points its distance from them is 12¼ inches, in other places the distance between them is 6 feet and even more where the length of the spans of the fixed wire is considerable.

The carrier consists of a grooved wheel *d* (fig. 164, page 379) and a curved iron bracket *e* is attached to the pivot on which the wheel rotates. The

bracket is bent sufficiently so as not to touch the hooks on which the fixed wire is supported intermediately. The bracket ends in a narrow hook.

FIGURE 164.

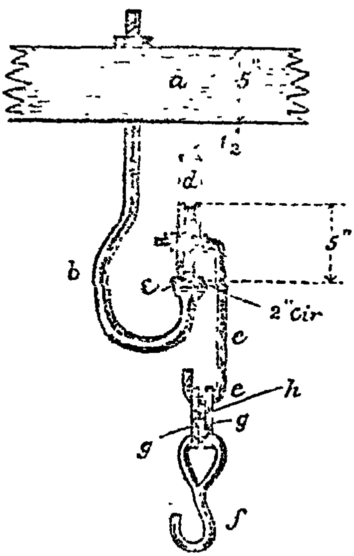


Figure 164 shows in elevation the carrier used on the Arbedo inclined wire rope near Belinzona in Switzerland for the transport of firewood; a *is part of the support from which the fixed wire rope is suspended;* b *is a strong curved hook furnished with a groove at the end in which the fixed wire* c *rests;* d *is the carrier. There are two carriers attached to each load of firewood. The carrier consists of a flanged wheel* d, *to the axis of which a strong hook* e *is fastened. The load is attached to the hook* f. *This hook is furnished with two rings* g g. *The hook is fastened to the bundle of firewood. The two rings are placed one on either side of the guide-rope* h *and on the hook* c *of the carrier, the weight suspended from the hook causes the two rings to clamp the guide rope tightly. (Scale=$\frac{1}{18}$).*

Two such carriers are fastened to each load of firewood, the attachment being made as follows :— a hook *f* is driven into the bundle of firewood and the two rings *g g* are placed one on either side of the guide rope *h* and then placed on the hook of the carrier. The hooked end (*e*) of the bracket is very narrow, so that the weight of the load causes the guide rope *h* to be jammed very tightly by the two rings (*g g*), and thus the load suspended from the carrier is fastened firmly to the guide rope.

The endless-moving rope passes round a horizontal wheel, which rotates round a vertical axis at either end. The velocity with which these wheels rotate is controlled by means of a steel ribbon brake. This brake is lined with wood and acts on half the length and half the breadth of the circumference of the wheels. The wire occupies the other half breadth and runs in a groove cut in the circumference of the wheel to receive it. One end of the ribbon brake is fixed to one of the uprights which support the wheel. This brake is very powerful, and one man has no difficulty in regulating the speed or stopping the wheel when it is necessary to put on or take off a load. There is a great strain on these wheels, and they are made very strong and firmly placed behind two horizontal beams which, in their turn, are placed behind two strong upright posts. The lower end of the vertical axis on which the wheel works in an iron socket is fastened to the lower horizontal beam. The upper end of the axis passes through an iron collar fastened to the upper horizontal beam. When a load arrives at the bottom of the fixed rope it is taken off with the carrier, and the unloaded carriers are returned up the second fixed wire rope, half a dozen carriers or more being hung on to one carrier placed on the fixed rope, so that their weight may allow of the moving guide rope to be firmly gripped.

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